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Volume 14 SEPTEMBER, 1953 Number 3

NOISE IN INDUSTRY 161
Aram Glorig, M.D.

INVESTIGATION OF THE USES OF ULTRASOUND IN EXPERIMENTAL MEDICINE 168
J. F. Herrick, Ph.D.

FLUORINE EXPOSURE DURING LOW-HYDROGEN WELDING 173
John J. Ferry

NEW DEVELOPMENTS IN REVERSE-JET FILTERS 177
H. J. Hersey, Jr.

CATALYTIC FUME ELIMINATION—Design Considerations for Application ... 183
R. J. Ruff

AN ARSINE PROBLEM—Engineering Notes 188
Glenn A. Johnson

DUST SAMPLING WITH A ROTATING THERMAL PRECIPITATOR 191
Herman Cember, Theodore Hatch and J. A. Watson

HEALTH SAFETY CONSIDERATIONS OF THE DISPOSAL OF RADIOACTIVE WASTES ... 195
Forrest Western, Ph.D.

SPECIFICATIONS FOR CALCULATING THE MEDIAN EFFECTIVE DOSE 200
Carrol S. Weil, M.A., Charles P. Carpenter, Ph.D., and Henry F. Smyth, Jr., Ph.D.

INDUSTRIAL HYGIENE BRIEFS: Illnesses Among Workers Cleaning Condensing Tubes 207
Harry E. Seifert

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION

News of the Local Sections 209

President's Page 211

In the News 212

Obituaries 213

Officers and Committees 214

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NOISE IN INDUSTRY

ARAM GLORIG, M.D., Director
Audiology and Speech Correction Center
Walter Reed Army Hospital, Washington, D.C.

FOR PURPOSES of discussion, the ear can be conveniently divided into three parts—the external, middle, and inner ear.

The external ear is bounded by the auricle externally and the external layer of the drumhead internally. It is about 25 mm. long and has an S-shaped curve directed inward, upward, and then backward. In order to see the entire canal the auricle must be pulled upward and backward. See Fig. 1.

The external ear serves as a conducting channel for sound. The auricle assists in localization by its shape and position but more so because of the flexibility of the motions of the head. When testing the function

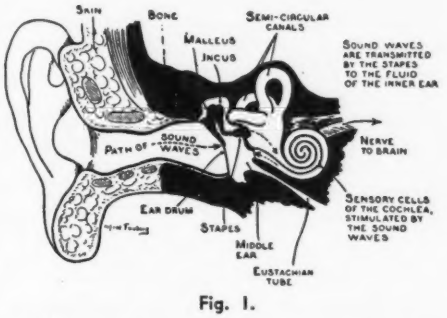

Fig. 1.

of the ear it is important to remember that the size and shape of the canal and auricle will influence the intensity of the stimulus at the drum. These influences are the result of cavity volume and standing waves, particularly when pure tones are used as stimuli.

The middle ear is bounded externally by the inner layer of the drumhead and internally by the mucous membrane covering the bony wall of the inner ear. Within this cavity are contained the three tiny ear bones, the "hammer, anvil, and stirrup" or medically speaking, the malleus, incus, and stapes; and two small muscles, the stapedius, which is attached to the stirrup or stapes, and the tensor tympani which is inserted at the hammer or malleus. The middle ear also contains three openings—the oval and round windows, and the opening to the eustachian tube. The oval window is fitted with the flattened bony plate of the stapes or stirrup. It is held in place by a fibrous membrane which surrounds the bony plate and acts as a hinge-like structure to allow the stapes to move as a trap door. This movement originating at the drumhead transmits vibrations to the inner ear. The round window is a tiny opening located just below and in front of the oval window. It is covered by a thin membrane which resembles the drumhead. The middle ear has three main functions: (1) The efficient transmission of sound vibrations from air media to fluid media. This is accomplished by a reduction in area from drumhead to oval window of about 30 to 1 and by the shape and attachments of the three small bones. (2) Protection for the inner ear. The stapedius and tensor tympani muscles act as a protective device by reflexly tensing the drumhead and ear bones and thereby stiffening the system which carries the sound vibrations across the middle ear. This acts to reduce the shock to the inner ear in case of high intensity sounds. (3) To maintain pressure equalization. The eustachian tube connects the middle ear with the posterior nasal cavity and serves to allow air to get into the middle ear in order to maintain equal pressure on both sides of the drumhead.

Presented originally at the AIHA Washington-Baltimore Section meeting, October 30, 1952 and also at the 23rd All-Ohio Safety Congress and Exhibit, April 15, 1953 at Columbus, Ohio.

The inner ear consists of two main parts, the semicircular canals, which contain the balance mechanism, and the cochlea wherein the hearing mechanism is housed. The cochlea is a long spiral shaped bony canal having two and a half turns. It contains a system of membranous canals and the end organ of the nerve of hearing. One canal travels up the spiral from the oval window and then turns to double back and end at the round window. The second canal is essentially a closed sack situated in cross section relation to the double canal as a wedge of pie is when a pie is cut into thirds. It is this closed sack which contains the highly specialized end organ of hearing or the *organ of Corti*. All of these membranous canals contain fluid making a hydraulic system out of the inner ear. Because this is so and fluid is incompressible, the two windows serve to allow fluid movement when the stapes or stirrup vibrates in response to movements of the drumhead as a result of air vibrations in the external canal. Motion pictures have been made which ably demonstrate that inward movement of the stapes produces outward movement of the round window membrane. This type of system allows wave forms to travel along the fluid of the double canal causing a fluid wave in the closed membranous canal, thus producing movements in the end organ which set up nerve impulses reported to the brain for interpretation.

The ear, its nerve tracts and physiological processes are an extremely complex mechanism. The external and middle ears are relatively well understood, but the inner ear, and especially the organ of Corti, is still pretty much a mystery. Recent advances in electronic instrument design have made it possible to approach the problem in a much more satisfactory manner, and obtain a great deal more information about the function of the inner ear.

In general, the young human ear can distinguish frequencies between 20 and 20,000 cycles per second. The frequencies important for speech intelligibility are contained between 300 and 3000 cycles per second. The speech area is further divided into the vowel and consonant frequencies. The vowel frequencies lie between 300 and 1500, and the consonant frequencies are within 1500 and 3000. Therefore, in testing the

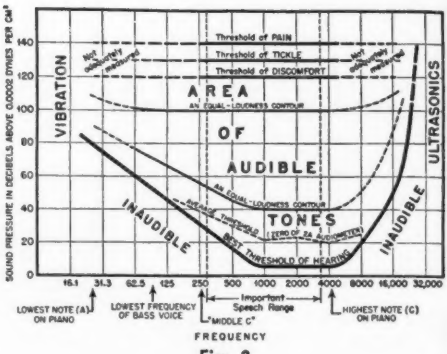

Fig. 2.

function of the ear for speech, two word lists are used—a so-called "spondee" list for the vowels and a "PB or phonetically balanced" list for the consonants. These two lists test respectively the "speech reception threshold" or determine the amount of volume needed before speech is heard, and "discrimination" or the ability of the ear to recognize the speech sounds well enough to repeat them. Most pure tone audiometers test between 125 and 8000 cycles per secone at octave steps—i.e., 125-250-500-1000-2000-4000-8000.

Intensity-wise the ear is most sensitive at 500, 1000, and 2000, and becomes less sensitive as the frequencies are decreased below or increased above this area.

Measurements of hearing are referred to "average normal hearing," the so-called zero reference level; and since these measurements are expressed in terms of "decibels of hearing loss" zero would mean no loss and any increase in output necessary to reach threshhold would be a hearing loss of so many decibels. See Fig. 2.

The decibel or "db" is a unit of measurement related to sound energy. It is based on a logarithmic scale to the base 10. This means that 20 db has 10 times the energy of 10 db, and 100 db would be equal to 10,000,000,000 (ten billion) times the energy of 1 db.

If the ear were more sensitive one could hear the air molecules bumping around in the external auditory canal. We know the drumhead moves about one tenth the diameter of a hydrogen molecule when stimulated at threshold. Is it any wonder that this delicate but hardy mechanism may

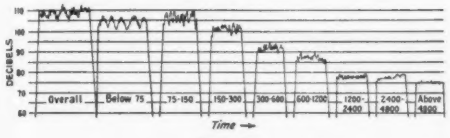

Fig. 3.
Noise in multi-engine bomber, treated with absorbing material. Analysis in octave bands.

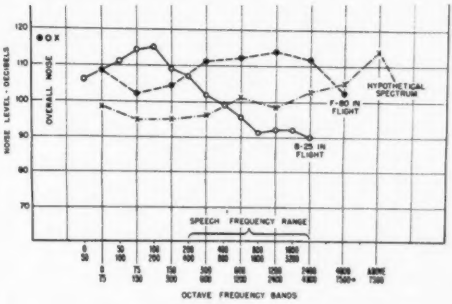

Fig. 4.

suffer injury when exposed to many billion times this amount of energy for any length of time?

Noise

WE HAVE DISCUSSED the ear briefly; now let us consider the problem of the "noise." First, how is noise defined? Simply, it is "any unwanted sound." For example, the last speaker on a long program; the yowl of cats at midnight; a cough during a concert or play; and any one of a dozen other examples.

Noise, like any other sound, is measured in two dimensions—intensity and frequency. The unit of intensity is the decibel, but in this case is referred to a different reference level than average normal hearing. Sound intensity produces pressure; therefore a reference of 0.0002 dynes per square centimeter is the point at which the decibel scale begins when the intensity of sound is measured. The unit for measuring frequency is the cycle; however, noise is such a complex sound it is usually measured frequency-wise in "octave bands," that is: 75-150, 150-300, 300-600 cycles per second, etc. See Figs. 3 and 4.

The decibel meter, or sound level meter, is the instrument used to measure intensity. It is a microphone with an amplifying unit and a meter based on the decibel scale. The db meter is adequate for noises of a more or less constant level and where the over-all noise level only is desired; however, for intermittent noises such as a punch press, a drop forge hammer, or a machine gun, the meter type instrument will measure only an average of the peaks that occur because of the inertia or latency of the meter. A specially calibrated oscilloscope is necessary for this type of measurement.

For octave band analysis work, the sound level meter or the oscilloscope is attached to a series of filters. This allows for checking the octaves at which most of the energy is concentrated.

Whenever noise measurements are considered, these two dimensions are mandatory.

Industrial noises of importance vary in intensity from 90-130 db (Fig. 5). Jet engines measure as high as 150 db (Fig. 6). Sound pressures as high as 180 db are found

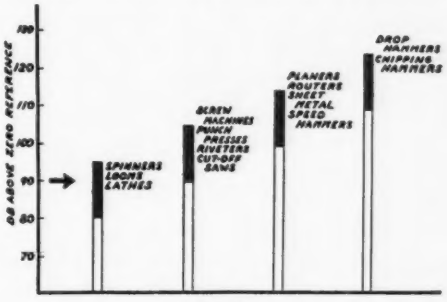

Fig. 5.
The over-all noise level typical in certain operations.

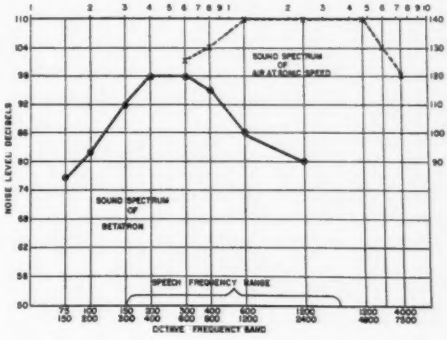
NOISE LEVEL DECIBELS
SOUND SPECTRUM OF AIR AT SONIC SPEED
SOUND SPECTRUM OF BETATRON
SPEECH FREQUENCY RANGE
OCTAVE FREQUENCY BAND

Fig. 6.

with gun explosions. Gunfire sounds are instantaneous and are probably more damaging than continuous sounds of a lot less intensity. The rise and fall time is less than 2-3 milliseconds. Little is known about the details of the effect of single peaks on the ear, but observation has demonstrated many hearing losses due to gunfire, particularly from small arms.

With increase in speed and power there is always an increase of noise. With the limits of speed and power nowhere in sight as yet, it appears that the human organism may be the limiting factor in man's attempt to mechanize himself.

Bio-acoustic Effects of Noise

HAVING LEARNED something of the anatomy and physiology of the ear, and the definition and dimensions of noise, we are ready to discuss some of the effects of noise on the human, with particular reference to the ear.

Much has been said and written concerning the effect of noise on the behavior of man. Some of these effects include nervousness, fatigue, inefficiency, sterility, and even death. In no case, however, is there any evidence to support any of these claims. As a matter of fact, the present evidence refutes this, except in the case of extremely loud noises such as are produced by afterburning jet engines.

The two important effects that can be supported with overwhelming evidence are interference with communication and the production of a hearing loss.

One merely needs to try to talk to his fellow worker in the presence of more than 90 db of noise to know the effect produced on communication. This phenomenon has been quite thoroughly studied and one can predict what the intelligibility of speech will be in the presence of specified amounts of noise.

Demonstrating the effect on hearing is readily shown by the production of a so-called "temporary threshold shift" of hearing. After exposing the ear to sounds above 110 db or so for a few minutes, audiometry will show a temporary hearing loss and after sufficient exposure time this temporary loss becomes permanent. See Figs. 7 and 8. It is certain that hearing loss is produced by noise, but there are many ques-

Fig. 7.
The course of recovery from one-half hour exposure to 110 db of noise from a plane without acoustic treatment.

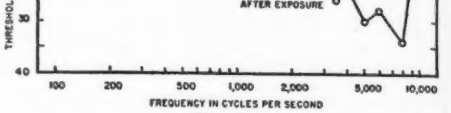

Fig. 8.
Hearing loss caused by long exposures to 115 db of noise simulating a bomber without acoustic treatment. With long exposures the effect spreads to the lower frequencies.

tions concerning this left unanswered at present. Some of these are:

1. How much noise is necessary?
2. What frequencies are most important?
3. What is the effect of individual susceptibility on the over-all problem?
4. How can we predetermine who is more susceptible?
5. How much exposure time is necessary?
6. When can the hearing loss be said to be permanent?
7. Is such a hearing loss progressive after removal from the noisy environment?

These are just a few of the multitude of questions to be answered by future research under controlled field conditions. This cannot be done, however, without the cooperation of industry over a period of not less than three to five years. Such questions can only be partly answered in the laboratory.

Hearing Conservation

ONLY WHEN all these questions and many others are answered can industry set up properly controlled hearing conservation programs. Until these answers are obtained industry must proceed along these lines:

1. All routine preplacement physical examinations must include air conduction threshold audiometry.
2. All individuals working in noisy areas suspected of having produced a hearing loss, whether temporary or permanent, should be followed with hearing checks every 6-12 months.
3. All suspected areas should be studied for possible noise reduction procedures.
4. Educational programs regarding ear protectors must be instituted.

Preplacement audiograms are necessary to protect both the employer and the employee. They establish the individual hearing baseline for future reference purposes —for example, to follow changes in hearing produced by the environment, and to establish any preplacement hearing loss. Incomplete surveys have shown that about 25% of applicants have a significant hearing loss.

Reduction of noise at the source should be attempted in all noisy areas. Such reduction can be done by enclosures, sound treating with absorbing material, or changes in machine design or mounting or both.

Ear protectors are a must in noisy areas. There are several presently available which are adequate for ordinary industrial noises. It should be the business of every hygienist and safety engineer to propagandize the use of ear protectors. The best ear protector is the one that is worn. Further research will probably produce more effective and more comfortable ear plugs. In the meantime every effort should be made to conserve hearing by example, education, and regulation. Many are against ear plugs because, they claim, when ear plugs are worn communication by spoken voice is impossible and warning signals are not heard. This assumption is fallacious. As a matter of fact, communication in noise is improved when ear plugs are worn. This is easy to demonstrate. Merely put your fingers in your ears while conversing in a noisy area; you will immediately notice that conversation can be heard much more easily. The same is true of warning signals.

Type of Hearing Loss

NOISE induced hearing loss is an irreversible nerve type loss. No known therapy will reverse the process. Such individuals have only auditory rehabilitation to turn to. Even this is difficult because the loss produced does not lend itself well to the use of a hearing aid, although with training and experience good results may eventually be obtained.

Implications

TWO IMPORTANT implications are evident at the moment. Compensation laws must be rewritten specifically for disability due to a hearing loss. This is not easy, although a combined committee of the Subcommittee on Noise in Industry of the Committee on Conservation of Hearing of the American Academy of Ophthalmology and Otolaryngology, and the Committee on Audiometers and Hearing Aids of the Council on Physical Medicine and Rehabilitation of the American Medical Association after two years' work is nearly ready to publish a document setting forth the principles upon which a rating schedule may be based. The rating scale itself has been set up but will not be ready for release until validation is complete—the percent disability is calculated upon the results obtained by testing for the speech reception threshold, and the percent discrimination for speech. This does not imply that pure tone testing is no longer necessary, only that a method of testing by speech has been added. A great deal of research has definitely shown that pure tone testing will quite accurately predict the speech reception threshold, but in terms of medico-legal validation it is much simpler to test directly with speech and not transpose from pure tone calculations.

The author, in cooperation with the Claims Division of the Veterans Administration, has formulated and put into operation a rating schedule based upon pure tone and speech tests. Either or both can be used when necessary but speech testing is the accepted method.

The medical profession hopes legislative bodies and the courts will accept these principles as the consensus of the experts and proceed to write compensation laws and rating schedules around them.

The second implication, probably more

properly called a complication, is "malingering." One writer has aptly called this "volitional deafness." At present malingering is very rare in industry where hearing losses are concerned but like all other "functional" disabilities, when compensation laws provide the added motivation "volitional deafness" will increase considerably.

Presently all routine standard hearing tests are based on subjective responses, which means the results can be colored by the intents of the subject. The accuracy of the results where malingering is attempted depends upon who is more clever, the tester or the testee. Because the problem of "volitional deafness" is considerable in the Armed Forces, a great deal of time has been and will be spent on the subject of "objective" hearing tests. The Audiology Service in conjunction with the Department of Neurophysiology at the Walter Reed Army Medical Center has just started an experimental review of objective methods in order to simplify the problem of discovering malingering. It is expected that a simple method of objective testing will be evolved in six to 12 months.

Equipment and Test Environment

INSTRUMENTS for measuring hearing may be divided into pure tone and speech audiometers. The pure tone instruments are called screening and diagnostic audiometers. Speech audiometers are just becoming available and at present are based on disc recordings or monitored so-called "live voice."

There are several makes of sound level meters and sound analyzers that are standardized by the American Standards Association.

Prices on these types of equipment vary between $300.00 and $1,000.00.

All hearing tests should be done in a quiet room. It is recommended that no more than 50 db of ambient noise be allowed in the room. Accomplishing this is sometimes difficult because of the location. A simple procedure is to locate an area where the ambient noise is low and yet relatively easily accessible. This should be away from elevators, water or steam pipes, outside walls where traffic noises abound, and noisy corridors. When a suitable location is found a double room about 8 x 8 x 7.6 high (inside measurements) should be built. As far as possible this should be a cubicle within a cubicle with *no* connections between the walls and as few supports between floors as possible. These should be rubber or felt blocks similar to hockey pucks or felt engine mounts (Fig. 9).

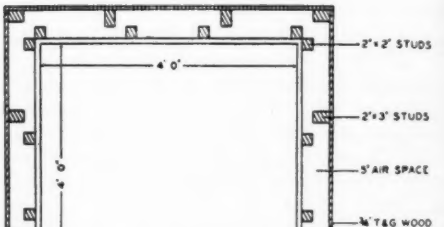

Fig. 9.
Diagram of a testing booth.

Activities in the Field

THE SUBCOMMITTEE on Noise in Industry of the Committee on Conservation of hearing of the American Academy of Ophthalmology and Otolaryngology has been active since 1946. In 1949 this subcommittee hired a field representative to study the problem in the field and laboratory. Since then a great deal of groundwork has been laid and access to industry (at first difficult) is becoming easier.

Recently the Armed Forces and the National Research Council combined to form a committee on Hearing and Bio-acoustics. This committee will guide the Armed Forces in the many ramifications concerning noise.

The American Standards Association, sponsored by the Acoustical Society of America, has a committee called Z-24-X-2, or the Committee on Bio and Psychoacoustics. This group is attempting to set up standards to control the noise problem in an over-all manner.

It is obvious that with these three committees the field of noise is well covered and a complete and speedy solution is inevitable.

Summary

1. THE ANATOMY and physiology of the ear in relation to noise are presented briefly.

2. Noise is defined as any unwanted sound and should always be measured in two dimensions—intensity and frequency.

3. The known effects of noise are in the main confined to those on communication and damage to the hearing mechanism.

4. Hearing conservation should be the guiding principle of the industrial physician, hygienist, and safety engineer where excessive noise is concerned.

5. The hearing loss produced by noise is an irreversible nerve type loss.

6. The two important implications of this problem presently evident are medico-legal and malingering.

7. There is adequate equipment easily available for measuring hearing and noise.

8. The American Academy of Ophthalmology and Otolaryngology, the Armed Forces and National Research Council, and the American Standards Association have organized very able and active committees to study their respective problems with noise.

[NOTE: All illustrations reproduced here were prepared by the Armed Forces Institute of Pathology.]

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3. *Proceedings of the Third Annual National Noise Abatement Symposium*, Technology Center, Chicago Illinois, October 10, 1952. Sponsored jointly by The Acoustical Society of America, The Acoustical Materials Association, The American Industrial Hygiene Association, The National Noise Abatement Council, and Armour Research Foundation of Illinois Institute of Technology.

4. *Guides for Industry*. Obtainable from HOWARD P. HOUSE, M.D., Chairman, Subcommittee on Noise in Industry of the Committee on Conservation of Hearing of the American Academy of Ophthalmology and Otolaryngology, 1136 W. Sixth Street, Los Angeles, California.

Noise Abatement Symposium

"OUTDOOR NOISE" will be the topic of the Fourth Annual National Noise Abatement Symposium to be held October 23 and 24, in Chicago. Papers on traffic, vehicle, and other city noises and on urban and industrial planning for less noise are being considered for presentation. Recent information on industrial noise also is being considered. Co-sponsors of the symposium are: National Noise Abatement Council, Acoustical Materials Association, Acoustical Society of America, AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, American Society of Safety Engineers, American Institute of Architects, Council on Industrial Health of the American Medical Association, American Society of Planning Officials, and Armour Research Foundation of Illinois Institute of Technology.

GEORGE L. BONVALLET, Associate Physicist at Armour Research Foundation, will be the program chairman. He will initiate the two day proceedings with "Outdoor Noise—What Is It?" UNO INGARD, Acoustics Department, Massachusetts Institute of Technology, Cambridge, Massachusetts, will speak on the "Physics of Outdoor Noise." DENNIS O'HARROW, Associate Director, American Society of Planning Officials, Chicago, will present "City Planning for Reduced Noise." The luncheon speaker, C. A. ARMOUR, Vice-Mayor, Commissioner of Police and Fire, Memphis, Tennessee, has chosen "Noise Abatement, Memphis Style" as his speech topic.

The program for the afternoon is as follows: H. WAYNE RUDMOSE, Technical Counsel, American Standards Association, Cambridge, Massachusetts, "The Relation of Hearing Losses to Noise Exposure in Industry"; HARRY A. NELSON, Director, Workmen's Compensation, Industrial Commission, Madison, Wisconsin, "Recent Noise Hazard Legislation and Its Implications"; WALTER F. SCHOLZ, Supervisor, Industrial Hygiene, Allis Chalmers Manufacturing Company, Milwaukee, "Combatting the Effects of Noise."

On Saturday, October 24, A. P. FUGILL, Detroit-Edison Company, will discuss "Noise Problems of Large Industrial Plants"; H. H. HUBBARD, National Advisory Committee for Aeronautics, Langley Field, Virginia, "Airplane and Airport Noise"; LEWIS C. KIBBEE, American Trucking Associations, Washington, D.C., "We Can Reduce Truck Noise." The symposium will be closed with the luncheon talk, "Noise and Culture," by V. O. KNUDSEN, Dean, Graduate Division, University of California, Los Angeles.

INVESTIGATION OF THE USES OF

Ultrasound in Experimental Medicine

J. F. HERRICK, Ph.D., Section on Biophysics
Mayo Clinic, Rochester, Minnesota

THE DUAL—diagnostic and therapeutic—use of ultrasound in medicine has aroused considerable interest during the past few years. Many papers, too numerous to mention separately in this report, have appeared. A few reviews[1-5] containing excellent references are recommended to anyone interested in a thorough study of the biologic effects and applications of ultrasound. This paper reports the results of investigations concerning the possible therapeutic uses of ultrasound.

General Background

PERHAPS the pain experienced by those working in ultrasonic fields was the first biologic effect observed. Langevin and Wood noted this, in 1917, when they were developing ultrasonic generators for use in underwater communication. Wood[6] stated, "If the hand was held in the water near the plate, an almost insupportable pain was felt which gave one the impression that the bones were being heated. This I thought was probably due to the fact that the waves were reflected by the bones, and that the very sensitive nerves of the periosteum were aroused by the process of arresting the radiation." Wood also reported that small fish were killed when they swam into the ultrasonic beam.

No doubt everyone who works with ultrasound has experienced this characteristic pain. The electronic engineer may make use of this pain-producing effect to determine whether or not a piezoelectric crystal is vibrating. If the thumbnail is pressed gently against the crystal at various angles between the thumbnail and the crystal, the pain will be felt as soon as the optimal angle is attained, if the crystal is vibrating.

Certain therapeutists rely on this characteristic pain for a determination of the upper limits of permissible outputs of ultrasonic generators. They warn the physician that the output control must be turned down immediately when a patient experiences the onset of pain in the surface of the bone. Whenever ultrasound is applied to hands, arms and legs, a pain may be felt at a point below the surface of the skin; as just indicated, this pain presumably is at the periosteum covering the bone. Measurements of thresholds of pain have been made by Hueter and associates[7-9] at the Massachusetts Institute of Technology. They reported that pain was felt in two seconds when the intensity was seven watts per square centimeter, whereas 60 seconds elapsed before pain was felt when the intensity was 1.7 watts. The frequency used in these measurements was 0.8 megacycle per second and the palm of the hand served as the test object.

Wood and Loomis[10] working in this country, made the first systematic investigations of the biologic effects of ultrasound; their results were published in 1927. Many studies on the biologic effects of ultrasound have been made in the United States and abroad during the succeeding years. The results of some of this work are confusing and contradictory because the exact conditions of the experimental procedures are not clearly defined or understood.

So far as I know, American scientists interested in ultrasound have not suggested its use for therapy. The earliest suggestions appear in the German literature in the years 1932 and 1933. Even today, the average physician in the United States is not enthusiastic about this relatively new therapeutic agent. This attitude deserves commendation in my opinion because ultrasonotherapy is in an unsatisfactory state at

This paper describes the results of a series of investigations with various colleagues. The separate studies, with the authors, are listed among the references.

present. This situation is to be expected when the application of a therapeutic agent gets ahead of itself, that is, when any agent is applied before an attempt has been made to learn its limitations and contraindications by means of experimental investigations. Objective measurements of the various effects produced by the proposed therapeutic agent should be made when possible.

The therapeutic value of ultrasound remains questionable in spite of several years of intensive study. This may be owing, in part, to the fundamental problems that exist in the pure science of ultrasonics, such as problems in propagation and generation of waves and in measurements, especially measurements in conditions of fine-scale nonuniformity. To produce a uniform field over a working area is a big problem—it is most difficult to obtain specified field conditions. A completely adequate theory for the propagation of waves has not been developed. Waves of large amplitude are not propagated without distortion. Energy passes from the fundamental to higher harmonics. Transformation from compressional waves to transverse shear waves may occur at interfaces. These shear waves, which travel along the interface, are attenuated rapidly, thereby producing considerable heat. Living organisms present a multitude of interfaces, so the problem of propagation of waves in living tissues presents added complications.

Review of the state of affairs in the pure science of ultrasonics allows full appreciation of the situation that confronts any investigator who attempts to understand the applied science of ultrasonics. Perhaps the urgency for the solution of certain problems in the applied science may result in some contributions to the pure science.

Specific Studies

ONE RELIABLE method for the investigation of certain therapeutic possibilities of a new physical agent is to study the effects of this agent on suitable animals; techniques recommended for therapy can be studied and certain pathologic conditions that occur in man can be simulated.

Investigations at the Mayo Clinic began in 1947, with a study of the effect of ultrasonic energy on malignant tumors. No other application of ultrasonics to medicine has had so much publicity. Several types of malignant neoplasms, both transmissible and spontaneous, are available in animals. My colleagues and I have failed to inhibit the growth of such tumors by use of ultrasound.[11,12] The malignant tissue could be destroyed by burning it with ultrasonic energy, but neighboring normal tissue was injured as well. That part of the tumor which was not burned continued to grow. An agent must act selectively on malignant tissue, with differential action on normal tissue, to be of intrinsic value in therapy. The first International Congress on Ultrasound held at Erlangen, in 1949, advised against the use of ultrasound for treatment of malignant tumors.

This failure to confirm the early reports of cure of cancer by ultrasound was most disappointing. However, these experiments convinced my associates and me that ultrasound was potentially a dangerous agent. Animals could be paralyzed when their spinal cords were exposed to ultrasonic power. Some small animals died during irradiation or shortly afterwards. Bones could be fractured; these fractures usually occurred nine days to a month after exposure.

THERMAL EFFECTS: Perhaps the most interesting effect observed during these preliminary studies on experimental animals and one which might prove of value in therapy was the fact that ultrasound is an excellent source of heat. Considerable time has been devoted since these earliest experiments to a study of these heating effects. Several enthusiastic therapeutists using ultrasound did not appear to recognize that this heating effect was the major one. They were aware of this effect but they considered that this particular type of heat was of secondary importance in therapy. It was generally assumed at first that the mechanical effects of ultrasound were the major and important ones. The heating effect of ultrasound in living tissues can be appreciated as soon as it is measured. Determinations of temperature in various tissues indicate clearly that nerves and bones are heated selectively by ultrasound.

Perhaps the most convincing evidence for this selective heating of nerve is found in microscopic examination of portions of muscle removed from animals after exposure to ultrasound. The muscle itself ap-

pears normal but the nerve is "cooked." The pathologist has observed repeatedly that small nerves, when present in muscle, may be damaged after exposure to ultrasound but the muscle remains uninjured, providing exposure intensity isn't too high.

Therapeutists using ultrasound recommend it highly in the treatment of conditions involving diseased nerves. They particularly recommend use of ultrasound for so-called sciatica. My co-workers and I have studied the effect of ultrasound on nerves. After exposure to ultrasound, the nerve may lose its ability to conduct impulses.[13] The question then naturally arises: Can this effect of ultrasound be used advantageously in therapy? The idea, obviously, is to try to render nerves nonconducting, that is, to block the nerves. This effect must be reversible to be of value in therapy. We found that when a nerve was exposed to ultrasound, its temperature was increased; the temperature of a given segment of nerve could be increased to any desired value. At given critical temperatures, the action potential of the nerve impulse could be reduced. If the temperature was increased slightly higher than this critical point, the amplitude of the action potential became zero and a permanent block of the nerve occurred. It was concluded from these experiments that the margin of safety between reversible and irreversible blocking of nerves is so narrow that the use of ultrasound for this purpose does not appear to be feasible unless further investigations result in better techniques for the prevention of permanent damage to the nerve. If the nerve was heated directly, the same effect could be produced more conveniently. We failed to see any significant difference between heating the sciatic nerve directly and exposing it to ultrasound. Unfortunately, neither heat nor ultrasound, as used experimentally, can be recommended for therapeutic use in the blocking of nerves.

The analgesic properties of ultrasound have been given considerable publicity by those using it in therapy. Experimental evidence for the production of analgesia may be obtained by observing the relative effects of ultrasound on nerve fibers, both sensory and motor. Each type of nerve fiber has a characteristic contour in the action potential recorded on the oscilloscope. Studies at the clinic presented no evidence for, or explanation of, the analgesic effect of either heat or ultrasound.[14] At the temperature at which the contour of the pain-carrying fibers was declining, the amplitude of the potential of the motor fibers was already decreasing.[15] Motor paralysis could therefore be expected to occur at temperatures that were capable of altering the conduction of some of the pain-carrying fibers. The analgesic property might have been explained if a great decrease had been observed in the amplitude of the pain-carrying fibers at a distinctly lower temperature than that which altered the conduction of the motor fibers.

It is most important to emphasize, however, that the results of these particular experiments, which were made on the isolated sciatic nerves of bullfrogs, may be quite different from those obtained on mammalian nerves. The intact sciatic nerve of the dog was studied but observations on differential effects on the various fibers were not made. The possibility must be recognized that an injured or diseased nerve may behave in an entirely different manner from the normal nerves that were studied. Thus, further investigations are required before a satisfactory explanation can be made for the analgesic property of ultrasound described by therapeutists.

The heating of bone by ultrasound is spectacular.[15,16] No other heating agent used in therapy can increase the temperature of bone to such high levels so quickly. The question that my associates and I have been attempting to answer is: Do we want to heat bone? The results of our studies thus far do not permit an answer to this question. The major factor that prompts extreme caution in the use of ultrasound at the clinic has been the possible damage to bones owing to the high temperatures developed by this agent.

A microscopic study of histologic preparations of bone after exposure to ultrasound has revealed osteogenesis, or formation of new bone.[17] Roentgenograms also demonstrated the formation of new bone. The first reaction to this observation was: Now we have something—a use for ultrasound that is of real value in therapy; this is something that we may learn to use advantageously and perhaps apply in the heal-

ing of bony defects and fractures. The problem is being studied at the present time. Bony defects are produced in both femurs of the dog. The defect in one femur is exposed to ultrasound, whereas the defect in the contralateral femur serves as the control. Although this investigation will not be completed for several months, it has been observed that the larger doses prevent the healing processes. The defect in the femur that is not exposed to ultrasound appears to heal more quickly. Obviously we have not yet learned the proper technique for forming new bone where it is desired.

Another problem being studied at present at the clinic is the effect of ultrasound on tumors of bone. My associates and I have demonstrated repeatedly that certain intensities of ultrasound inhibit the growth of bone[18]; therefore it would be expected that ultrasound should inhibit the growth of tumors of bone. The first step in this investigation is the production of experimental tumors. It was learned from the literature that certain compounds of beryllium cause tumors in the bones of rabbits.[19] We have successfully reproduced the technique described for the production of these tumors and are just beginning to study the effect of ultrasound on them.

NON-THERMAL EFFECTS: Unlike other sources available for therapeutic heating, ultrasound also produces non-thermal phenomena; among these are (1) increased permeation of ions through membranes by stirring effects, (2) resonance effects, (3) chemical effects and (4) cavitation. Heat may accompany, modify or follow some of these consequences.

Cavitation includes certain phenomena that occur in the medium propagating the sound wave. Obviously the word means formation of a cavity. However, a simple definition of this phenomenon is difficult, because different types of cavitation may occur. Some authorities distinguish the types as gaseous and vaporous. Others classify these phenomena as pseudocavitation and true cavitation. The classic work on the theoretic aspects of cavitation was done by Rayleigh.[20] Excellent papers on this aspect by other scientists also appeared in the literature.[21,22] Some authors stated that the phenomena occurring during certain types of cavitation defy theoretic analysis and that the mathematics for such analysis has not been developed as yet.

Since my colleagues and I are fundamentally experimentalists and not experts in theoretical physics, we attempted to look for evidences of the phenomena of cavitation in biologic systems after ultrasonic irradiation. Certain well-known authorities in ultrasonics have stated that cavitations do not occur in biologic systems when the conditions recommended for therapy obtain. We observed burns in the intestine during a study of the effect of ultrasound on the Walker rat carcinoma. This was to be expected at tissue-air interfaces, where almost 100% reflection of the energy takes place. In addition, petechial hemorrhages were observed in the intestines. When Dr. Lehmann came to the laboratories of the clinic in January, 1952, he continued a study of these petechial hemorrhages that had been started in Germany. Microscopic examination of these extremely minute hemorrhages revealed evidences of cavitation in the nature of localized rupture in walls of blood vessels. These hemorrhages could be prevented by irradiation of the animal while it was subjected to high pressures. The hemorrhages could be produced more readily with low than with high frequencies. These investigations indicate that such petechial hemorrhages are caused by cavitation;[23] further evidences of cavitation occurring in tissues are being sought.

Comment

THE ATTITUDE of therapeutists using ultrasound has changed from the assumption that the therapeutic value of ultrasound depended primarily on its mechanical effects to an acceptance of the fact that the major role of ultrasonic energy in therapy is its heating effect. Since the effect of ultrasound on tissue is primarily thermal, the reason for its use in therapy may be questioned because other excellent types of heating agents are available. Ultrasound must accomplish a unique type of heating to gain admission to the armamentarium of the therapeutist. This requirement leads to a brief consideration of how ultrasound differs from other heating agents.

As mentioned previously, no other heating agent used in therapy can increase the temperature of bone to such high levels so

quickly. This unique heating of bone by ultrasound is caused by the difference in acoustic impedances between muscle and bone. The specific acoustic impedance of bone is of the order of magnitude of $4.2 \cdot 10^5$ gm./cm.^{2}/sec. The specific acoustic impedance of muscle is approximately the same as that of water, namely $1.5 \cdot 10^5$ gm./cm.^{2}/sec. Such a mismatch of impedances gives rise to the phenomenon sometimes described as "structural" heating, which occurs at abrupt interfaces. In structural heating, considerable energy becomes dissipated in the form of heat because the ultrasonic energy is lost through scattering, through multiple reflections and, under certain conditions, by the generation of highly damped shear waves.

Another great mismatch of impedance occurs in the living animal at a tissue-air interface; such interfaces may be encountered when ultrasonic energy is propagated through the wall of the intestine or whenever ultrasonic energy emerges from the tissues into the atmosphere (points of exit at body surfaces and also in the lungs). The specific acoustic impedance of air is 40 gm./cm.^{2}/sec., whereas the specific acoustic impedance of tissue is approximately $1.5 \cdot 10^5$ gm./cm.^{2}/sec. About 99.9% of ultrasonic energy is reflected back into the tissues at a tissue-air interface. Such a situation produces severe burns.

Schwan and Carstensen[24] stated, "This localized heating at interfaces, characteristic of ultrasonic diathermy, has no parallel in other forms of energy therapy such as electromagnetic diathermy or pure conduction heating." The unique type of heating just described may be a potential hazard until therapeutists learn to use it properly and advantageously. Nevertheless, ultrasound stands alone as a method for heating interfaces and, as already stated, the living body is a maze of interfaces.

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FLUORINE EXPOSURE

during low-hydrogen welding

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THE COMPARATIVELY recent introduction of the low-hydrogen coated electrode has introduced the potential hazard of fluoride inhalation during metal arc welding on mild steel. While fluorides have been used in the coatings of stainless steel and other high alloy electrodes for years, these electrodes have never found the large-scale, general usage that may be expected for the low-hydrogen coated electrode. Thrysin, et al.,[1] have reported the growth in the use of this electrode in Sweden. The same growth may be expected here.

In anticipation of the increased use of this electrode, a series of tests have been conducted, in the laboratory and under actual manufacturing conditions, to determine the concentration of fluorides to which the welder might be exposed under different welding conditions.

LABORATORY TESTS: The first stage of the investigation was carried out in the laboratory, where methods and procedures could be most readily developed. The following data were obtained:

1. The electrode coating contained approximately 9% fluorine, principally as calcium fluoride. Less than 1% of this fluorine was water soluble. The electrodes produced by one manufacturer only were studied; it is probable that composition will differ with different manufacturers.

2. The fumes contained 10% to 12% fluorine. The percentage of fluorine varied with the distance from the arc to the sampling equipment, and was evidently influenced by the presence of relatively large slag particles. Over 50% of the fluorides in the fumes were water soluble. (Thrysin, et al.,[1] have reported fluorine concentrations ranging from 17.1% to 28.2% in the fumes from basic (low-hydrogen) electrodes. They do not report the concentration in the original coating. They also report increased water solubility of the fluorine content of the fumes.)

3. A 3/16" low-hydrogen electrode produced approximately 0.6 gm. of fumes.

4. No significant amount of hydrogen fluoride or other gaseous fluoride could be determined.

Several methods were tried in order to arrive at the most accurate and most convenient method of collecting samples to show the welder's exposure. After finding that samples collected at different locations outside of the helmet (front, back, and side) varied by several hundred percent, it was decided to sample inside the helmet. This was accomplished by taping a rubber tube with the intake close to the welder's mouth and drawing air through filter paper. This was the method used in succeeding sampling. Results of preliminary laboratory sampling are as follows:

No.	Location	Milligram of Fluorine per Cubic Meter
1	Front of helmet	28.0
2	Side of helmet	18.0
3	Rear of helmet	12.0
4	Side of helmet	30.0
5	Rear of helmet	0.35
6	Rear of helmet	1.40
7	Inside of helmet	0.7
8	Inside of helmet	2.8
9	Inside of helmet	1.4
10	Inside of helmet	1.4

These results have little significance except to indicate the range of concentration which could be expected. Since they were taken under different conditions (except 5, 6, 7, and 8) no correlation of results was

expected. Samples 5 and 7, and 6 and 8, were taken simultaneously. It is interesting to note that the concentration inside the helmet in both cases was exactly twice that immediately behind the helmet.

The efficiency of filter paper as a collecting medium for welding fumes was established by comparison with the electrostatic precipitator.

ANALYTICAL METHODS: Fluorine was determined by distillation and titration with thorium nitrate.[2]

SAMPLING PROCEDURES: Two types of samples were collected during the study:

1. Breathing zone samples: These samples were collected under the helmet in the manner previously described. They give an accurate picture of the exposure of the individual during actual welding conditions. The samples were for the most part collected for approximately 30 minutes of welding time. By welding time is meant that time when the helmet was being worn and includes arc time, and time for changing electrodes and slag removal. Local exhaust ventilating systems were not used during the collection of the samples, in order to show conditions in the absence of such systems. Frequently, 60 to 90 minutes were consumed in securing the 30 minute welding time sample.

2. General air samples: These samples were collected in the general room air away from the direct path of welding fumes and show the concentration to which everyone in the area was continuously exposed. These samples were collected for prolonged periods, 30 to 120 minutes, to secure a better picture of average conditions. General ventilation, whether mechanical or natural, was not deliberately altered during these samples. Local exhaust ventilation was not in use during the day sampling was carried on.

AREAS STUDIED:

1. Area A: Welding here was on large castings, pre-heated to 300° to 400° F. by open gas flames. Because of the high temperatures, welders worked in pairs, one working, the other resting. While the locations being welded were principally in the open, it was sometimes necessary for the welder to crouch over the work, or to weld in a partially confined space. The work was mostly filling or repair welding. The arc time was low, estimated at under 20%. The welders were on day work. General ventilation was good. Electrodes of 3/16 and 5/32 inch were used.

2. Area B: This was a pipe shop, with pipes up to 18" in diameter being welded. The work was located in a large open shop with good ventilation. The work called for extreme accuracy in welding, but most of the time was devoted to arrangement of the pieces and tacking. The arc time (not estimated) was quite low. Welders were on day rate. Electrodes of 5/32 and 1/8 inch were used.

3. Area C: This was a large open shop, with welding done on a variety of cold castings. The work did not call for extreme accuracy, and welders were on day rate. General ventilation was good. Electrodes of 3/16 and 5/32 inch were used.

4. Area D: These samples were collected while welding pipes inside large tanks. The pipes were 4" to 6" in diameter. The tanks were very roughly 10' x 10' x 10' and had openings on top approximately 2' x 3' and an opening on one side approximately 4' x 4'. The welding was done at heights ranging from knee to shoulder level. Extreme accuracy was required. Arc time was low. Local exhaust ventilation was not used during sampling. Good general ventilation was in effect outside of the tanks. Electrodes of 5/32 and 1/8 inch were used.

5. Area E: This was a large crowded welding shop. Work was on large fabrications (10' x 10' x 10' or larger) and encompassed almost every conceivable position and location. Welders were on piece work, and arc time was high, about 50%. The low-hydrogen coated electrode here was limited in use to the first pass on any given weld. For the balance of the work, conventional coated electrodes were used. It was estimated that the low-hydrogen electrode was used on less than 25% of the welding on any particular job, and less than 10% of the total welding in the shop. However, those samples shown in Table I were collected only when the low-hydrogen electrode was being used. Electrodes of 3/16 and 1/4 inch were used. General ventilation was fair. All welding in this area was in the open.

6. Area F: This is the same shop as described in Area E with the same general conditions prevailing. However, in this case,

TABLE I.
BREATHING ZONE SAMPLES
FLUORIDE CONCENTRATION

Concentration* Range	Number of Samples in Area— A	B	C	D	E	F
0-0.5	9	2	1	2	0	1
.5-1.0	7	2	2	2	2	3
1.0-1.5	2	2	0	0	1	2
1.5-2.0	1	0	0	0	0	1
2.0-2.5	1	1	0	0	0	1
2.5-3.0	0	3	0	0	1	1
3.0-3.5	0	1	0	0	1	1
3.5-4.0	0	1	0	0	1	1
4.0-6.0	0	0	0	0	1	1
6.0-8.0	0	0	1	0	1	0
8.0-10.0	0	0	0	0	3	0
	20	12	4	4	11	12

*Milligram of fluorine (—F) per cubic meter of air sampled

all samples were collected while welding was being carried on in what can best be described as semi-confined areas. The degree of confinement of the fabrications being welded varied greatly, but in no case were more than five sides, assuming a cubical enclosure, closed. Again, only the low-hydrogen electrode was in use during collection of the samples shown in Table I. Electrodes of 3/16, 1/4 and 5/16 inch were used.

Results

RATHER than show the individual samples, which would have little meaning unless the exact sampling conditions were known, the results have been summarized.

Table I gives the number of samples collected in the various areas, and the concentration range into which they fell. These samples were all collected while the low-hydrogen electrode was being used exclusively. No local exhaust ventilation was in use during the sampling period. These samples give the actual exposure of the welders during their welding time.

Table II gives the results of the samples collected in the general atmosphere in the various areas. These represent the background exposure of the welder, to which he is more or less continuously exposed. Since several of these samples were collected in areas crowded with welding operations, it is very possible that abnormally high results were produced by location of the sampling equipment directly in the path of the welding fumes.

Table III shows results of samples collected in Areas E and F, when the conventional coated electrode was being used. In this case, the total weight of welding fumes is reported. These samples were collected in order to estimate the fluoride concentration which could be expected if the use of the low-hydrogen electrodes should be extended.

Discussion

AS WOULD be expected, the concentration of fumes to which the individual welder was exposed varied tremendously with the difference in jobs. No correlation existed between the various areas studied, or even within the areas. In fact, there appeared to be no correlation of exposure between welders on almost exactly the same job.

Several interesting facts were noted regarding the exposure of welders to fumes, both total and fluoride.

1. Piece workers received greater exposure than day workers. This might be expected, since their arc time would be normally greater.

2. Welders on heated work had less ex-

TABLE II.
GENERAL AIR SAMPLES
FLUORIDE CONCENTRATION

Concentration* Range	Number of Samples in Area A	B	E
0. -0.02	0	0	0
0.02-0.04	0	0	1
0.04-0.08	3	0	7
0.08-0.16	2	2	4
0.16-0.32	1	1	1
0.32-0.64	1	0	1
	7	3	14

*Milligram of fluorine (F—) per cubic meter of air sampled

TABLE III.
BREATHING ZONE SAMPLES
TOTAL FUMES

Concentration** Range	Numbers of Samples in Area E	F
0-5	0	1
5-10	1	0
10-15	10	0
15-20	5	3
20-30	2	5
30-40	2	1
40-60	5	3
60-80	2	2
80-100	0	1
100+	1	
	28	16

**Milligrams of total fumes per cubic meter of air

posure than those on cold work. This was probably due to the fact that they tried to remain as far as possible from the work surface.

3. Work calling for accuracy involved greater exposure, presumably because of the tendency to lean closer to the work.

4. Confined, or semi-confined, areas did not result in as high exposures as was expected. If there was no way for thermal currents to carry the fumes from the enclosure, the concentrations would, of course, be very high. If there was a path open, the concentrations were not significantly higher than those determined at similar operations in the open room. This is illustrated by comparison of B and D, and E and F in Table I, and by Table III.

5. Electrode size was not a deciding factor in exposure. Just as many high concentrations were determined using the smaller electrodes as the larger. Where other factors did create a high exposure, however, a larger electrode made the exposure higher.

6. The individual working habit of the welder created the greatest variable in fume exposure. This may be influenced by vision, by previous instruction, or simply by indifference. One possible explanation, given by several welders, was that since they could not see anything but the arc, they did not realize that they were in the path of the fumes. The introduction of a material in the coating to produce an odor would probably be advantageous.

In Table I, Area B, tests were run on three welders doing exactly the same job. The five highest concentrations shown were determined on one welder. This difference in exposure among different welders on the same job was noticed repeatedly during the tests.

Summary

IT WAS NOT the purpose of this report to evaluate the possible hazard from inhalation of fluorides during welding with the low-hydrogen electrode, rather to show the range of concentrations which may be expected under various conditions. It must be pointed out that the concentrations reported cannot be correlated to the threshold limits unless welding time and actual time are synonymous.

Our results did indicate that with continuous welding the fluorine (F—) concentrations may be far below the generally accepted limit of 2.5 milligrams per cubic meter of air in some circumstances, far above it in others.

It is felt that the actual degree of hazard associated with the use of this electrode will depend on the amount of fluorine in the coating, the welding conditions, the individual welding habits, and the arc time.

It is felt that the number of variables is too great to permit accurate evaluation of the degree of hazard by air sampling, unless every job of every welder is examined. Urine analysis offers an easier and probably more accurate solution.

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Research in Instrumentation for Prevention of Industrial Health Hazards

New Developments in Reverse-Jet Filters

H. J. HERSEY, JR., Engineer, New York City

THE HERSEY method of filtering dust and some types of fume from air and other gases is not just another way of cleaning bags of accumulated dust, as is often supposed by those not familiar with the principles of this method and their application.

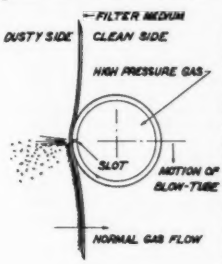

Fig. 1.
Relation of blow-tube to filter medium.

It is distinguished by the use of a thick dense filter medium which increases the effectiveness of the filtration processes of impingement and diffusion in the capture of the smaller particles, and the screening out of the larger. Because it does not rely upon the bridging of interstices such as exist in woven fabrics for its dust retention efficiency it can filter at much higher velocity, which means less filtering area to maintain, and less space requirement. Porosity of the filter is maintained by a jet of high velocity air in reverse direction to the normal flow, which moves progressively over the filter medium. This is accomplished by means of a slotted tube which actually contacts, in fact indents, the filter medium—an essential consideration which distinguishes the method from the "blow-back" filters which appear in patent literature and which are consequently incapable of producing similar results. (Fig. 1)

The basic mechanics of the method in its simplest form consists of one or more wool felt tubes which are surrounded by slotted rings moved up and down by chains or cables, and fed with low pressure air by a hose from a positive displacement blower, or a high pressure centrifugal fan. Fig. 2 illustrates an early form.

Extended industrial application of the reverse-jet filter has demonstrated both strengths and weaknesses, and has led to developments and inventions for making this relatively new type of filtering dust collector of greater usefulness and scope. This paper attempts to explain some of the less obvious problems, features, and possibilities of the reverse-jet filter.

Control of the Jet Action

IN AN ASSEMBLY of 12 foot-long tubes only one-half of 1% of the filtering area is affected by the porosity maintaining action,

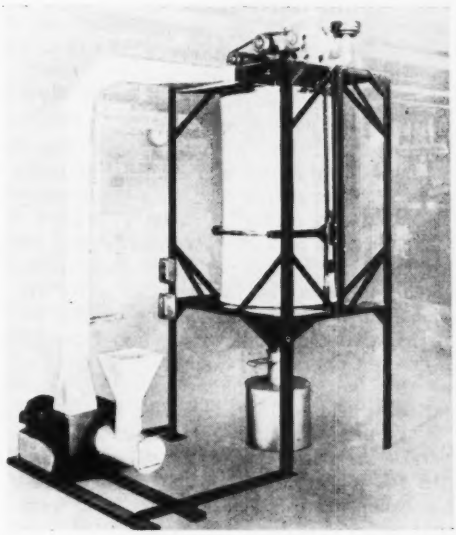

Fig. 2.
An early model of the Hersey reverse-jet filter.

Presented at the Fourteenth Annual Meeting, AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, April 23, 1953, Los Angeles.

and there is no compartmentalizing of a section being cleaned which loses the controlling factor of prevailing pressure. Consequently a degree of automatic control is possible which has not before been attainable. This provides constant volume irrespective of variations in the amount or character of the dust. Constant volume is essential to the efficient operation of any dust collecting system but has heretofore not been obtainable where filters were employed. Time-cycle operation does not accomplish the same result because the resistance of a filter is not a function of time, but of the amount and character of the dust, and of atmospheric conditions. The value of control by the pressure drop is well demonstrated by an installation recently observed at a smelter crushing plant where the volume would otherwise vary between 20,000 and 26,000 CFM Fig. 3) with three dusts of different physical properties and each producing different amounts of airborne dust according to the moisture content of the parent material. The pressure control switch is set for design volume with the maximum normal quantity of dust, although the dust load occasionally exceeds that for short periods. This setting is 21,000 CFM at 3.0" water gauge pressure drop with 15 grains per cubic foot, under which condition the jet operates all of the time. However, the dust load is usually below 15 grains and between 10 and 1 grains, reverse-jet operation is only 30% to 12% of the time with the volume variation automatically held to 13%. See Fig. 4.

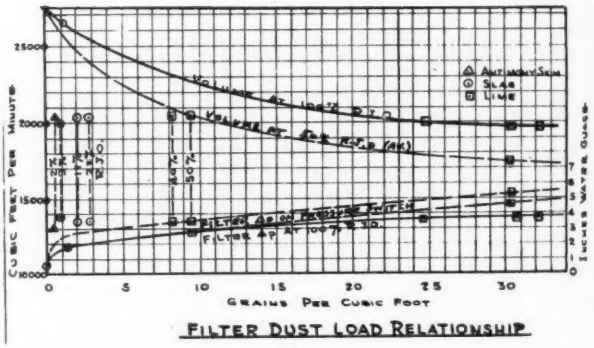

Fig. 3.
Variation in system performance (ductwork filter, and fan) with changing dust load to filter.

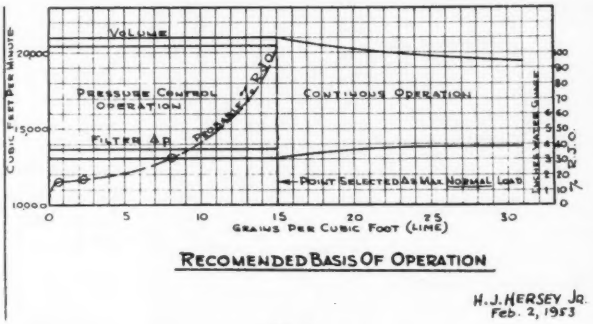

Fig. 4.
System performance with pressure control operation of filter. Same system as shown in Fig. 3.

A reverse-jet filter will almost always operate at a lower average pressure drop with the jet in continuous operation. (The only exception is when the dust is of such a character that time for agglomeration or flocculation aids the jet in removing it to such an extent that an occasional trip over the filter surface is more effective in terms of average pressure drop than continuous trips which keep it dispersed, and redepositing.) The lower pressure drop may, however, be expensive in terms of varying air volume, higher maintenance and lower dust retention efficiency.

TABLE I.

	Grain	Flour	D	Chem. D	D	A
Av. Dust Load—grains per cu. ft.	0.60	0.92	6.9	7.7	8.0	13.1
Filtering Velocity—ft. per min.	19.5	13.3	6.7	6.7	6.7	6.7
Av. Pressure Drop—Continuous "H_2O	4.33	1.3	5.0	5.0	5.0	4.6
Av. Pressure—Control "H_2O	5.15	1.6	7.0	6.2	5.7	6.0
Increase in Pressure Drop	0.82	0.3	2.0	1.2	0.7	1.4
%RJO with Control	6.5%	14.5%	29%	33%	64%	24%

Table I shows the results of many hours of recordings of the cost, in terms of pressure drop, of several percentages of reverse-jet operation under control by pressure drop, on several field applications.

In the lower ranges of reverse-jet operation percentages, there will usually be additional power cost but the saving on high pressure reverse-jet offsets the cost of the higher pressure drop on the main fan.

The saving to be had in maintenance through control by pressure drop is obvious, and where applicable, is justified by that alone.

Dust retention efficiency has been pointed out by Silverman and others to be affected by the reverse-jet action—disturbance of the dust deposit causing some particles to sift through even dense wool felt. Therefore it follows that the less reverse-jet activity, the higher the average collection efficiency. Automatic control of the jet to the minimum required to maintain constant volume is certain to provide higher overall efficiency than constant reverse-jetting. Table II, taken from Harvard Air Cleaning Laboratory Progress Report NYO 1586, shows approximately four times the penetration through the felt of talc with 100% as compared to 45% jet operation, one and a half times on vaporized silica with 100% as compared to 10%; and three and a half times on precipitated fly ash with 100% as compared to 7%.

A principle reason for the early development work on the reverse-jet filter in 1939 was the concept of fully automatic control of the porosity maintaining action by the pressure drop, so as to maintain the dust deposit to assure the high efficiency needed in silicious ore crushing plants where low dust counts were demanded. Use of reverse-jet filters since on so many non-toxic heavy load applications has delayed the full recognition and development of this feature which seems to be justified.

It is often remarked that extremely high efficiency is not essential because a dust is non-toxic, or the location is remote from habitation. This is reasoning of questionable merit in view of the accelerating march of progress in control of air pollution; the increasing recognition that few if any dusts are unharmful to all people; and the fact that few locations long remain remote.

If a filter is justified at all, it should be an efficient filter and the purpose of the Hersey filter development is to provide the optimum benefits of filtration with maximum convenience and versatility in application.

TABLE II.
EFFECT ON COLLECTION EFFICIENCY OF REVERSE JET OPERATION TIME

Air Flow Rate CFM/ sq. ft.	Test Dust	Filter Resistance— in. W.G. Avg.	Dust Loading Grains/ 1000 cu.ft. in	out	Reverse Jet Operation time %	Dust Penetration % by Weight
11.5	Talc	—	140	.00025	45	0.0019
11.5	Talc	4.72	160	.00125	100	0.0078
10.0	Vaporized Silica	—	1070	.001	10	0.00093
10.0	Vaporized Silica	5.1	1260	.018	100	0.0014
9.5	Fly Ash	—	1120	1.0	7	0.023
10.0	Fly Ash	1.06	1240	0.25	100	0.082

Filter Medium Treatments

OCCASIONALLY a dust is encountered which does not form a sufficiently stable deposit even in dense wool felt, to stand any reverse-jet action at all without some leakage, which although not visible as air-borne dust, may in some cases be objectionable. It is not a matter of particle size, as some of these dusts are very coarse compared to some which are retained at extremely high efficiencies. It has been noted that those few dusts exhibiting this behavior are non-flocculating. Static electrical charges do not appear to have a bearing on seepage, because a fine bronze powder dust carrying no measurable charge, presents a seepage problem. Also, pigment grade TiO_2 in the order of one micron or less in particle size and which has a tendency to flocculate, presents no seepage problem, but the same chemical, in a Technical Grade, having 8 to 10 micron particles that do not readily flocculate, presents a serious seepage problem.

When given a special treatment, known as HCE, the tendency of dusts to seep through felt is practically eliminated. In the instance of the bronze powder mentioned above, it eliminated all visual evidence of seepage. The same was true with Technical Grade TiO_2, certain resins, cement dust, starches, etc.

The most complete and accurate investigation to date, of the effectiveness of HCE

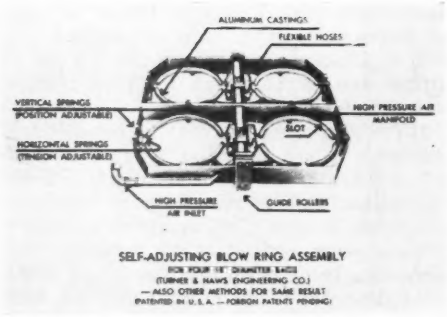

Fig. 5.
Self-adjusting blow ring assembly.

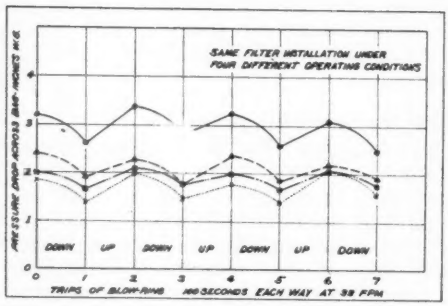

Fig. 6.
Redeposition indicated by variation in resistance of a single tube with position and direction of blow ring travel.

treatment over plain felt was made by K. J. Caplan and M. G. Mason in the test of a reverse-jet filter collecting a radioactive dust, most of which was less than one micron in particle size and exhibited excessive seepage through plain felt. Their tests showed that at the end of 110 days' service a plain felt bag gave a collection efficiency of 99.25% whereas an HCE treated bag at the end of 158 days' service had a collection efficiency of 99.920%.

Self-Adjusting Blow Rings

As was pointed out in the first part of this paper, the contact with, and even indention of, the filter medium is of primary importance. For optimum performance it is critical within narrow limits. An adjustment of only ⅛ inch, in terms of radius, made in the field recently, increased volume from 22,800 CFM to 26,300 CFM and reduced pressure drop from 6.9 inches water to 5.9 inches in a few minutes of operation.

Wool felt, and probably any other material with like filtering properties, is inherently dimensionally unstable, and in any case the need of perfect alignment of tubes is an undesirable requirement. Consequently, it has been deemed necessary to provide for this with means for automatic adjustment relative to the tube diameter and alignment. As diameter cannot be changed except within the limits of the elasticity of the tube material without the formation of wrinkles with consequent wear, it is necessary to oval the tube cross-section by means of segments which are of somewhat greater radius than the tube itself.

A means of accomplishing this, as developed by Turner & Haws Engineering Co. is shown in Fig. 5. Various needed design features were disclosed by this development, and other designs of self-adjusting rings will soon appear, but with the same objectives.

Wear of clean wool felt by smooth metal surfaces is negligible in the absence of chemical attack or other adverse conditions, as proven by tube life of over four years to date on some of the early installations. However, uniform conditions must prevail if such service is to be obtained. Self-adjusting rings offset such variables as tube stretch, uneven stitching, and occasional unexpectedly high pressures due to accident or maladjustment in the system or collector.

Redeposition

The capacity of reverse-jet filters is adversely affected by redeposition of part of the dust removed by the jet, especially when it consists of readily dispersed nonflocculating particles of relatively low apparent specific gravity. With tubes relatively long in relation to diameter, a window reveals that there is almost no settlement of fine dust into the hopper except as the reverse-jet approaches it on the down trip, indicating redeposition is taking place at all other times. The importance of this action is also indicated by plotting resistance in a single tube against the vertical position and direction of the jet, (Fig. 6) which shows it decreasing as the lower extremity of travel is approached. Still another proof

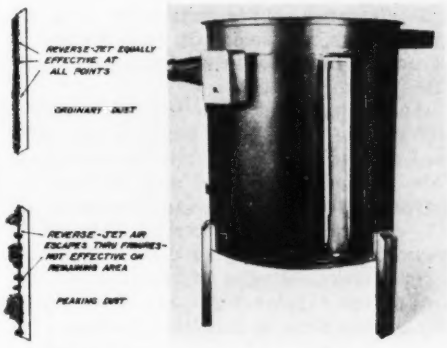
REVERSE-JET EQUALLY EFFECTIVE AT ALL POINTS
ORDINARY DUST
REVERSE-JET AIR ESCAPES THRU FISSURES-NOT EFFECTIVE ON REMAINING AREA
PEAKING DUST

Fig. 7. Fig. 8.

Fig. 7: Illustration of fissures and pinholes formed by an excessively thick surface deposit of some dusts. Fig. 8: External view of rotary-arm type filter. (Shown without hopper.)

is that experiments and observations show that most of the retained decrease in resistance occurs on the down travel—recent recorded tests on cement dust showing 80% on down trip. The up-trip lessens the rate of pressure rise by disturbance of the particles deposited within the medium, but it does not dispose of an appreciable amount of the surface deposit. This is readily explained by calling attention to the presence of the cleanest portion of the filtering area immediately below the jetted dust cloud when the rings are on the up-trip.

The ideal solution to this problem would seem to be isolation of the jetted dust, with conveyance directly to the hopper. Patent literature is full of ideas for vacuum cleaning of the filter surface which perhaps had this problem in mind but overlooked the secondary separation required at the point of deposit, and of course lack of ability to retain the desired equilibrium deposit discussed earlier in this paper.

Thick Surface Deposit

ANOTHER cause of low capacity in some reverse-jet filter applications is the tendency of some dusts to flocculate or cling to the surface to such an extent that an excessively thick surface deposit is formed. The reverse-jet opens only pin holes or fissures in such deposits, the air flow resistance of which is less than the pressure required to form more of them, or to remove agglomerates. In such a case, the jet

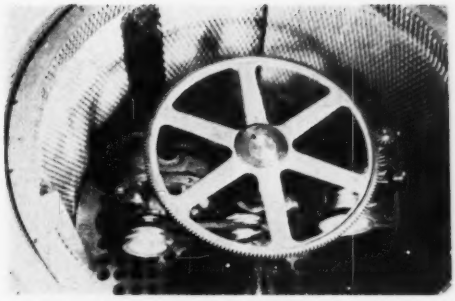

Fig. 9.

Internal view of rotary-arm type, from above, showing blow-tube between screen support and filter, and drive mechanism for central shaft.

only acts through these small openings, which is in effect the same as reducing the total of the active filtering surface to their total area (Fig. 7). The ideal solution to this problem would be to pass a fine taught wire, or the like, so close to the filtering surface that a deposit of such thickness could not accumulate. As a practical dust collector design does not lend itself to the precision positioning such an ideal approach would require, a compromise has been made in the form of what might be called wipers, or sweepers. Their action is difficult to describe in that they do not brush or sweep off the thick deposit as implied—which action would, of course, shorten the life of the filter medium. Instead, they gently contact it just enough to disturb the cake that has been formed, and to interfere with further formation. They also tend to fill the fissures or pin holes, with resulting increase in their resistance, and better distribution of the effective pressure of the jet on its next passage over the filtering area.

New Forms of Reverse-Jet Filters

IN AN EFFORT to overcome the limiting factors in performance previously discussed, a method of applying a reverse-jet in a way which would attack them in basic fashion was conceived. Dimensional instability of the filter medium was offset by mounting it on a screen support; redeposition attacked by providing a receiver to isolate most of the jetted dust from the cleaned surface; means for mounting a wiper to prevent excessive accumulation of deposit provided; and one-directional motion to avoid rever-

Fig. 10.

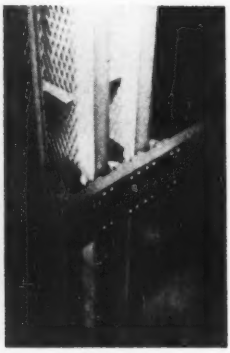

Fig. 11.

Fig. 10: V-panel style from front, or "dusty" side. Fig. 11: V-panel style from clean side, showing blow-tubes and manifold. Drive mechanism not shown.

sal and the consequently less effective uptrip arranged for, by an assembly such as illustrated by Figs. 8 and 9, which is a test unit shown without the hopper.

A central tubular shaft carries a slotted blow-tube around the cylindrical expanded metal screen supporting the filter medium. Opposite, on the dusty side, and supported from the same central shaft is the receiver, in, or adjacent to which, is a wiper of any desired form. The essential in this, or like design, is the interpositioning of the blow tube between the filter medium and its support to provide the perfect contact and indentation of the filter medium referred to in the early part of this discussion as necessary for good results. In order to meet this requirement the blow tube has to be of very thin cross section, and both it and cylindrical screen support must be designed and assembled with sufficient precision to provide clearance, but a minimum of it, between them. Consequently this method of reverse-jet application is not easy to translate into large sizes.

Another application of the interpositioning of the blow tube between the filter medium and a support for it, is the V-panel form shown by Figs. 10 and 11 which illustrate only an experimental section of two V's or pleats. In commercial form there would be a multiplicity of these pleats. This form attacks only one of the limiting factors of the tubular form, which is dimensional instability of the filter medium. It is similar to the tubular type in all other respects, being actuated by the same type of reciprocating mechanism (not shown here). However it offers maximum filtering area in relation to space requirement, and in a rectilinear form for use on large volumes of air of relatively light dust content.

Conclusion

IN CONCLUSION, it might be said that the reverse-jet type of filter presents a filtering method which is capable of much higher filtration velocities at the same or higher efficiencies than previously experienced. Experimentation and analytical study of results obtained in several years of field application point the way to still further advances, some of which, discussed in this paper, are already accomplished, on an experimental and/or field application scale.

Unfortunately, at least for the experimenters, the reverse-jet principle adds several more interdependent variables to the already complex basic facts of filtration. Nevertheless, progress to date indicates future improvement in a tool for dust collection and air filtration.

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Catalytic Fume Elimination

DESIGN CONSIDERATIONS FOR APPLICATION

R. J. RUFF, President, Catalytic Combusion Corporation, Detroit

INDUSTRY and the general public are presented almost daily with new products and processes resulting from this age of rapid scientific and technological progress. When, occasionally, such presentations are dominated by imaginative publicity, the consumer may hopefully look upon the new development as a "cure-all." Ultimately, however, as limits and potentials are field-proved, the new development assumes its rightful position as determined by its fundamental soundness and conformance with natural and economic laws.

From the field experiences of four years and several hundred production installations, the range and limits of catalysis as applied to specific fume combustion applications can now be predicted with a reasonable degree of accuracy. It is, therefore, the purpose of this report to review the function of the catalyst in combustion of flammable type fumes, define the limits of adaptability, specify results obtainable, and outline the influencing design factors of a complete catalytic fume combustion system.

Early development work on the use of catalysts for fume combustion was motivated by the concept of energy reclamation. The oxidation of any hydrocarbon or organic gas causes heat liberation as well as conversion of the noxious fumes to innocuous carbon dioxide and water vapor. For example, a typical industrial paint baking oven may liberate and exhaust to the atmosphere 10 gallons of paint solvent per hour. It is obvious, therefore, that the release of latent energy in the exhaust stream —on the basis of a heat of combustion value of 120,000 BTU per gallon of solvent —represents a significant heat recovery potential of 1,200,000 BTU/hr. While this paper will be confined to the properties of catalytic oxidation for air pollution control, the number of installations, where fume elimination simply becomes a by-product of energy recovery, is constantly increasing.

Presented at the Fourteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Los Angeles, April 23, 1953.

Definitions

THE catalytic concept of fume elimination requires the employment of terms and expressions infrequently used in other air pollution control work. For convenience of the reader, and to permit condensation of report material, the following simplified definitions are listed:

Catalyst: A substance which, simply by its presence, accelerates a reaction without itself entering into the end products of the reaction. As applied to fume combustion, the presence of the catalyst permits union of oxygen and hydrocarbons, in a fume stream at approximately 500° F, when in its absence probably 1400° F would be required for the same reaction. Since the catalyst does not become part of the end products, its life is theoretically infinite.

Fume Energy Concentration: The latent heat energy in a unit of fume stream, usually expressed as BTU volume per cubic foot of 70° F equivalent air (BTU/SCF). By thermal capacity of dry air, the release of each BTU/SCF will produce increments of temperature rise to the fume stream of approximately 57° F. Therefore, the combustion of a fume stream having an energy concentration of 10 BTU/SCF will produce a temperature rise to the fume stream of 570° F.

Lower Flammable Limit—L.F.L. or L.E.L.: The lowest concentration of a mixture of flammable vapor or gas in air (usually expressed in percent by volume) in which a flash will occur, or a flame will travel, if the mixture is ignited. A point-source of

high temperature is required to initiate the chain reaction. Over 600 flammable gases are classified indicating L.E.L. ranges from 1% for carbon disulphide to 4.1% for hydrogen. These variations undoubtedly result from differences in molecular weights and oxygen demands, since the energy concentration for all flammable gases at the L.E.L. appears generally constant—in the range of 50 BTU/SCF at room temperature.

Catalytic Ignition Temperature: The minimum temperature to which a fume stream must be raised to initiate or cause catalytic combustion. Platinum alloy catalysts are employed for their recognized stability, low ignition temperature, and resistance to elevated temperatures. At operating velocities, catalytic ignition temperature may vary from below 300° F for alcohols to as high as 600° F or more for the highly refractory vapors of tar and asphalt. Variations in energy concentration from traces to 3 or 4 BTU/SCF produces no significant change in catalytic ignition temperature.

Oxidation System

IN THE sequence of fume movement from its source of generation in a manufacturing process to the discharge of the oxidized gases, a complete system generally incorporates the following parts:

1. Fume Collection and Delivery. This may consist of an exhaust fan on a paint baking oven, or tight-fitting hoods and fume collection ducts on kettle cooking operations.

2. Fume Preheating Equipment—required whenever the process exhaust gases are below the required catalytic ignition temperature. Preheating can be accomplished by oil, gas or electric heating.

3. Temperature Control and Limit Protective Devices. In addition to controlling the preheating equipment, it may on occasion be necessary to control fume energy concentration and oxygen supply, by air dilution or by other methods, to maintain concentrations within prescribed safety standards.

4. Insulated Housing with Catalytic Elements.

5. Heat Recovery or Self-recuperative Systems.

Fig. 1.
Typical catalyst element for organic fume incineration.

The catalyst element is similar in appearance to a metallic air filter mat. The supporting media for the precious metals consist of a nickel alloy ribbon "fill" supported between nickel alloy container screens, all enclosed within a heat-resisting alloy channel frame. A coating of the platinum alloy metal is bonded to the nickel alloys and conditioned for activity. The construction permits high through-put capacity, low resistance to flow, high heat resistance, permanent distribution of the catalyst surface area, and resistance to thermal or mechanical shock. Standard elements may be installed in "banks" for any desired fume volume.

The activity life of such catalysts has not yet been fully explored. Several units have now exceeded 23,000 service-free operating hours, and many units, checked after 10,000 hours of operation, show no measurable reduction in activity. It is expected that over long periods, normal attrition will cause activity to decline. When this occurs, the elements may be reactivated.

Range and Limits of Application

CATALYTIC oxidation is broadly applicable to hydrocarbon and organic type fumes, including alcohols, esters, ketones, ethers, acrolein, and aldehydes, as well as hydrogen, carbon monoxide and mercaptans. Equally satisfactory results are obtained

with the low boiling group as well as the dense, heavy vapors liberated in the cooking of oils, tars and asphalt. Preheating prior to catalysis causes the visible aerosols to return to a pure gaseous state, thereby preventing condensate formation.

From the standpoint of initial cost, there are no serious volumetric limitations. Several systems have been supplied for volumes as low as 20 CFM and others, with capacities of over 20,000 CFM.

Because of the requirements for preheating to catalytic ignition temperature, operating costs may increase directly with the volume, but inversely with fume energy concentration. As an example, a 10,000 CFM, self-recuperative catalytic fume-removal device, receiving fumes at room temperature, having an energy concentration of 4 BTU/SCF would be essentially self-sustaining, on a continuous basis, requiring no external heat. The same system handling an air stream containing an energy concentration less than 0.1 BTU/SCF would require an operating consumption of approximately 2,400,000 BTU/hr.

The limits of adaptability from the standpoint of energy concentration or continuity of the fume load is again primarily economic. For those applications where the fume energy concentration is constantly within the flammable range, direct ignition by flame, without use of catalysts, appears to be the logical procedure. Catalytic fume removal systems have already proved their use over several years of operation on fume streams which may fluctuate below, within, and above the flammable range, such as the exhaust from hooded varnish cooking kettles.

The process is considered unsuitable for use where the fumes contain large amounts of cinders, inorganic solids, or vaporized metals that would cause rapid deterioration of the catalyst, as in foundry cupolas, blast furnaces, or coal-fired boilers. However, normal atmospheric dust causes no difficulty, and, in some cases, low concentrations of process inorganics can be tolerated. In general, observation of the manufacturing process generating the fumes will indicate whether permissible concentration of inorganic solids may be present in the exhaust stream.

Although their use is comparatively rare, some types of halogenated hydrocarbons are harmful to the catalyst. The temperature of the fume generating process may influence their presence in the exhaust stream. Where questions exist as to suitability of the process, pilot units may be connected to the exhaust stream in the field. The accumulated data from several hundred pilot plant installations is now helpful in predicting results on each new application.

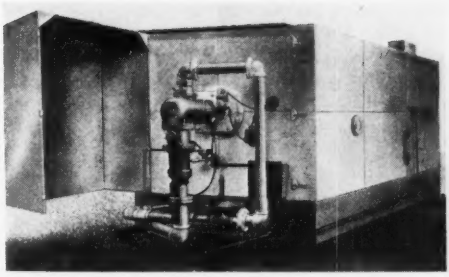

Fig. 2.
Catalytic fume combustion unit complete with gas pre-heat burner and controls as used for handling exhaust fumes from heat-set inks in the paper printing industry.

Operating Results

PUBLISHED reports by independent authorities have credited the catalyst with complete removal of organics in atmosphere, to as low as "zero" scale deflection on an infrared spectrometer. This same result can be accomplished where necessary—for instrumentation purposes and for laboratory work. However, for full-scale production installations, expected combustion efficiencies will vary from 97.5% for fume energy concentrations of 1 BTU/SCF, to higher efficiencies for higher fume concentrations. Physical inspection of the effluent stream normally shows results as follows:

Color	None.
Eye irritants	None, or slight trace.
Condensate in exhaust ducts	None.
Odor	Non-objectionable.

Results as tabulated above are being obtained on production installations that have been operating for six months or more for such process exhaust applications as:

Foundry core-baking oven using linseed oil and similar core binders.

Oil cooking kettles—animal, vegetable, mineral, and fish oils.

Fig. 3.
Battery of catalytic fume combustion units installed for deodorizing fumes produced in the manufacture of phthalic anhydride. Shown are 10 of 28 units which have been operating 24 hours per day for the past three years.

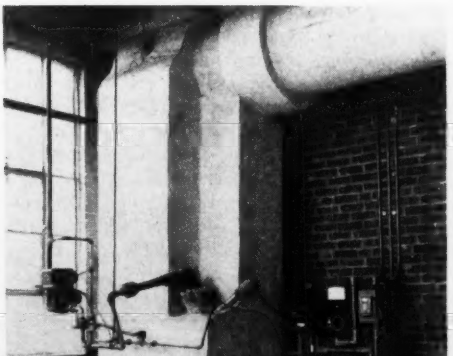

Fig. 4.
Catalytic fume incinerator installed for eliminating noxious odors produced in the manufacture of resins and varnishes for paint finishes. Unit serves two 1000-gallon cooking kettles.

Alkyd resin cooking kettles for paint manufacturing.

Phenolic resin curing oven.

Dryers of high-speed paper printing presses, using heat set inks.

Oil burn-off furnace used in vaporizing kerosene and light oils from transformer punchings.

Kiln for firing wax-bound ceramics.

Organic chemical plant manufacturing phthalic anhydride, with gases containing maleic anhydride, phthalic anhydride, naptha quinone and napthalene.

Wire enameling ovens, with gases containing xylols and coal tar derivatives.

Design Data Requirements

STANDARDIZATION of catalytic combustion systems has now been adopted for several fume combustion applications. This has been accomplished primarily in the wire-enameling field, and on kettle cooking operations where either the processing equipment, or method of processing is essentially the same from one manufacturing plant to another. However, because of the wide variance in factors influencing the designs of the complete system, it appears evident that the majority of the installations will continue to require individual engineering study and design. A field study of a potential application, prior to design development, includes investigation of:

1. Manufacturing process causing fume generation.

2. Nature of fumes, their rates of liberation, or cyclical behavior.

3. Exhaust volume requirements of the process. In some cases, the volume of diluting air can be materially reduced with safety, thereby increasing fume energy concentration, reducing volume, equipment, size, installation and operating cost, while improving the opportunity for profitable heat recovery.

4. Control and safety equipment existing in the fume generating process, and possible desirability of interlocking with the safety controls of the catalytic system.

5. Presence of condensate in existing ex-

haust lines to determine the need for elimination of such hazards.

6. The opportunity and potential use for reclaimed heat, where fumes have high energy concentration. This may involve further studies on heating requirements for plant make-up air, steam generation or adjacent drying operations.

Summary

ALL TOO often air pollution is viewed as contamination primarily from soot, flyash, and other forms of solid matter. However, analyses of smogs causing irritation to the eyes, nose and respiratory tract, as well as damage to crops and reduced visibility, prove that major pollutants are frequently hydrocarbons, or their products of decomposition, present in the form of gases and aerosols.

By fortunate circumstance, harmless end products result from the complete combustion of hydrocarbons. Through the development work of the past four years, during which the range of applicability for effective and economical utilization of catalytic fume combustion has been established, industry's heating and ventilating engineers are given new responsibilities and opportunities in the field of air pollution control.

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5. "Paint Company Beats Odor and Fume Problem with Special Measures." Martin E. Schleicher, Technical Director, McDougall Butler Company, Buffalo, New York.

6. "Fume Disposal by Catalytic Combustion." Harold F. Borger, Plant Engineer, Hilton-Davis Chemical Company, Cincinnati, Ohio.

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Industrial Hygiene Section of APHA

THE INDUSTRIAL Hygiene Section of the American Public Health Association announces the following program to be presented at the annual meeting of the Association during the week of November 9, at the Statler Hotel in New York City. The program is a preliminary one, and final details will be announced later:

November 10, 9:30 A.M.: "Pneumoconiosis of Coal Miners in the United States," DR. JOSEPH MARTIN, Elkins, West Virginia; "Diatomite Pneumoconiosis," DR. H. K. ABRAMS, Chicago, Illinois; "Health Educational Techniques in an Occupational Cancer Program," speaker to be announced; "Maximum Utilization of Industrial Hygiene Personnel," DR. IRVING TABERSHAW, New York City.

November 10, 2:00 P.M.: Business meeting of Section.

November 11, 9:30 A.M.: Joint session with Medical Care Section on "Impact of Labor Health Plans on Public Health," A symposium including presentations of several experiences and a paper by DR. W. A. SAWYER on "Labor Health Programs—A New Opportunity for Promulgating Occupational Health."

November 11, 2:00 P.M.: Joint session with Engineering Section on "Integration of Environmental Health Programs," speakers to be announced.

November 12, 9:30 A.M.: Joint session with Sections on Epidemiology, Statistics and Food and Nutrition, "Methodology of Chronic Disease Studies," speakers to be announced.

November 13, 9:30 A.M.: Joint session with Sections of Health Officers, Public Health Nursing and Health Education on "Cooperation between Local Health Departments and Industrial Hygiene Personnel.

An Arsine Problem

—ENGINEERING NOTES

GLENN A. JOHNSON, Industrial Hygiene Engineer

ARSINE is considered one of the most toxic and insidious gases; a maximum allowable concentration of 0.05 parts per million has been suggested by the American Conference of Governmental Hygienists. Industrial poisoning is often unexpected since very small amounts of arsenic, present only as an impurity, can result in dangerous quantities of arsine.

The poisoning reported in this paper occurred during a leaching operation for the recovery of cadmium as a secondary output of a zinc smelter. The operation is carried out in a covered tank, No. 9A, eight feet in diameter, and vented to atmosphere by a stack which extends about 10 feet above roof level. The tank is located at ground level just outside the south wall of the leach plant building. The operation proceeds as follows:

A recirculating liquor from one of the subsequent stages is put in the bottom of the tank and is made strongly acid by the addition of concentrated sulfuric acid. The resultant liquor is neutralized by roasted cadmium bearing dust which is brought to the tank by screw conveyor. The recirculating liquor and the dust contain zinc, iron, lead, and arsenic as impurities, the recirculating liquor containing about 60 mg./liter of arsenic. The tank mixture is mechanically agitated and heated by direct steam injection.

The brief history which follows was established two days after the accident:

At about 8:00 PM on Wednesday evening, February 6, 1952, a severe reaction occurred during the addition of concentrated acid to No. 9A tank. The shift foreman, who was inside the building at the time, noticed an acid reaction odor (which resembles that of fried onions) so strong that he thought the tank had boiled over. Upon investigation, however, he noticed that the stack effluent seemed to be blowing down into the building. Both of the men who were subsequently hospitalized were working inside the building at the time—one on the third floor cleaning a filter press and the other on the floor below pressing briquettes of cadmium sponge. The man pressing briquettes started to leave the building toward No. 9A tank; his co-worker stopped him and they both went outside the building on the side opposite the tank. These men reported that the odor was noticeable at some distance away from the building. The worker at the filter press reported that he had not noticed any unusual odor; it was later discovered that the drip pan under the press was drained to No. 9A tank.

At about 10 PM on Thursday evening, 26 hours after the severe reaction, the worker who had been cleaning the filter press reported to his foreman that he was passing red-colored urine. The plant physician was notified, and the man was hospitalized for observation. Arsine poisoning was suspected; but since this man had been taking medication for an anemic condition, it was felt that the hemoglobinuria might be due to causes other than arsine. Early Friday afternoon it was learned that the worker who had been pressing briquettes had also been voiding red-colored urine since Thursday evening. He was likewise hospitalized. By this time urine samples of all the men on that shift were in the laboratory for arsenic determination. The urine of the two hospitalized workers showed 1.0 and 0.6 mg./liter of arsenic, while the other four workers on the same shift showed 2.0, 1.0, 1.0, and 0.7 mg./liter of arsenic. These values were not corrected for specific grav-

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This study was conducted by MR. JOHNSON while associated with the St. Joseph Lead Company, Zinc Smelting Division, Monaca, Pennsylvania. He is now with The Inland Steel Company, East Chicago, Indiana.

ity. The two men who were hospitalized made uneventful recovery and returned to work after 12 days of lost time each. The other men did not lose time, but two of them received medical attention. The arsenic in urine levels of the workers on the other shifts were between 0.05 and 0.20 mg./liter except for one value of 0.35 mg./liter.

Prior to the accident, operations of No. 9A tank had been checked for arsine generation and at no time was it possible to find arsine outside the tank. Following the accident, the operation was checked again; no arsine was found outside the tank, although two to three parts per million could be detected over the liquor inside the tank. Sampling was done with a Willson welding fume hand pump adapted to hold mercuric chloride and lead acetate papers. Color stains were compared with the British standards[1] and corrected for sample volume. The hand pump is convenient for checking potential sources of arsine; to determine levels as low as 0.05 PPM, an unreasonable number of pump strokes is required.

In order to prevent further exposure to arsine, a ventilating system was designed to control all potential hazard points. The system provided exhaust ventilation for 17 tanks. For the most part, these were previously vented to the atmosphere by wooden natural draft stacks extending above roof level. Many of the tank liquors are agitated mechanically or with compressed air and heated by direct steam injection. The tanks have lead or cypress covers with various openings for inspection and operational purposes. The basic design figure chosen for the system was five cubic feet of air per minute per square foot of surface area. If all cover openings are closed, the volume exhausted is reduced; since no solids are handled, there is no need to maintain a minimum velocity in the ducts. The design figure proved to be adequate except for two tanks with large openings near the vent stack. The exhaust volume for these was increased 40%. All of the wooden stacks were left in place; connections were made to the stacks at convenient points and the stacks dampered above those points. In case of exhaust fan break-down, the tanks can be vented through the stacks.

The exhaust gases are extremely corrosive; a warm, condensing, acid condition exists. For this reason, the system is constructed of Type 302 stainless steel throughout. Since no dust or abrasive material is handled in the system, light gauge sheet was used—24 gauge for ducts nine inches in diameter and larger; 26 gauge for all ducts smaller. Ductwork is of crimped and riveted construction. Several gas welded elbows were initially installed but failed at the welds from corrosion. The light gauge stainless ductwork has served well since installation with a minimum of maintenance required.

The exhaust mains from different sections of the building lead into a chamber about five feet high by four feet wide and 10 feet long. This chamber serves to eliminate condensate droplets which are carried toward the fan through the ducts. The chamber is provided with a drain and trap. The fan inlet is connected to the chamber near one end and the fan discharges into a nearby 168 foot masonry stack. The fan is a Buffalo 60-inch industrial exhauster completely rebuilt in the plant shops of Type 304 stainless steel. While the stainless model was being built, a similar fan of standard construction was used. In spite of several coats of acid-resistant paint, the impeller blades of ¼-inch mild steel plate were corroded into uselessness in a few weeks. The stainless fan has been in service over a year and shows no sign of deterioration.

During the period after the accident, before the ventilation system was installed, all leach plant workers left the building during the addition of concentrated acid to No. 9A tank. An air sampling program was undertaken to locate all possible arsine sources. Ordinarily, no arsine could be detected during normal leach plant operations. Several of the operators on each shift were taught the use of the hand sampling pump. In this way, an unusual occurrence at any time could be checked. This proved to be invaluable in uncovering several arsine sources which had not been previously considered. One of these is of interest. About a month after the ventilation system was installed, one of the workers noticed an odor near a filter press on the third floor while a batch was being made in No. 9A tank. Several tests for arsine were posi-

tive; the source being the drain from the drip pan under the press. The drain led into No. 9A tank; elimination of this connection was simple. The discovery of this source helped to explain the exposure of one of the workers who had been hospitalized. The assistance afforded by the leach plant personnel was of much value; in addition, these workers gained a better understanding of the hazard and of the value of exhaust ventilation.

Following the arsine poisoning, routine checks of arsenic in urine, red blood cell count, and hemoglobin were established for all leach plant employees. Each employee is checked every four weeks. The employees are divided into two groups, scheduled so that a set of determinations is made every two weeks.

The chemical method for arsenic in urine utilizes direct generation of arsine from the urine in a Gutzeit generator. This method is sufficiently sensitive for screening purposes. Arsenic in urine values have been below 0.1 mg./liter and are usually less than 0.06 mg./liter which are well within the normal range.

Some interesting conclusions may be reached by a study of the blood test results. The average red blood cell counts have not shown any significant change, remaining at about 4,900,000. Hemoglobins are determined with a Haden-Hauser Hemoglobinometer. The average hemoglobin value has shown a gradual rise from 85% to about 90% over a period of 40 weeks, as indicated in Fig. 1. Each point represents the average of about 25 determinations, one for each of the employees who worked in the leach plant prior to the accident on February 6, 1952. The average length of employment at that time was about five years. The coefficient of linear correlation for the values from 0 through 40 weeks is

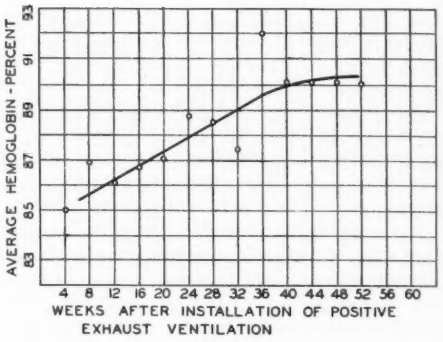

Fig. 1.

0.85 which indicates a fairly strong relationship. The average hemoglobin value seems to be leveling off above 90%, and this compares favorably with the average plant value of 92%.

It is apparent that leach plant hemoglobin values were lower than would be expected prior to the installation of exhaust ventilation, and it is probable that this was due to a chronic exposure to arsine. The exposure was not severe enough to produce any marked symptoms prior to the episode of February, 1952. Arsenic in urine levels of those workers not exposed at that time were below 0.20 mg./liter. A continuous workday exposure to 0.05 PPM of arsine would result in a urine level of 0.20 mg./liter if 50% of the inhaled arsenic were eliminated in the urine.

It is concluded that an exposure to arsine at levels as low as 0.05 PPM may result in reduced hemoglobin values; return of hemoglobin to normal is slow after elimination of the exposure.

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Expert and Technical Testimony

THE UNIVERSITY OF MICHIGAN announces a "Conference on Expert and Technical Testimony in Medical and Health Problems," offered by the Institute of Industrial Health and School of Public Health. The conference will be held Wednesday, October 21, 1953. The program is planned to present concise, fundamental information regarding rudimentary principles of court procedure, the obligations and privileges of expert witnesses and the rules, practices and limitations that govern testimony.

Dust Sampling

WITH A ROTATING THERMAL PRECIPITATOR

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Department of Occupational Health, Graduate School of Public Health
University of Pittsburgh

IN 1935, Green and Watson[1] described a thermal precipitator for dust sampling and determination of atmospheric particle concentration and size distribution. This instrument was based on the work of Aitken,[2] who demonstrated that hot objects are surrounded by a sharply delineated dust free space, the dimensions of which depend on the thermal gradient surrounding the hot body. When the temperature gradient is high, the force acting on the particle in the direction of the thermal gradient is sufficient to precipitate the particle on the cold surface. Green and Watson's thermal precipitator consists of an electrically heated nichrome wire, 0.007 inch in diameter, held taut midway between two cold microscope cover slips which are separated by 0.015 inch. The thermal gradient is steep enough so that the dust free space surrounding the wire intersects the cover slips as the air passes between them and the hot wires. In consequence, the dust particles are precipitated on the cold cover slips.

As predicted by theory, the particles are precipitated according to size in the direction of air travel. As a result of this sizing process, any one microscopic field does not contain a random size distribution, and size measurements must therefore be made across the entire deposit. In order to eliminate this disadvantage, several improvements have been incorporated into the original device. One such improvement was initiated by Walton et al[3] who built a thermal precipitator with an oscillating collecting plate. The microscope slide is mounted in a carriage that is caused to oscillate by a motor driven cylindrical cam.

This work was performed under U.S. Atomic Energy Commission Contract Number AT(30-1)-912.

This paper describes another method for obtaining a uniformly dispersed dust sample which is achieved by rotating the collection plate. In this manner the instrument may be more easily made and may be of smaller dimensions.

Description of the Instrument

THE DESIGN and operation of the instrument may be explained with the aid of Fig. 1. Parts A and B are held together with two screws to form the body of the instrument. Part B has a 1 cm. wide x 0.010 inch deep air channel milled longitudinally across the center. A nichrome wire C, 0.010 inch in diameter, is held in the ceramic insulator D. Tension is maintained by the use of spring E. The center line of the wire is in the plane of the bottom of the channel, thus providing a gap of 0.005 inch between the cold collecting plate and the hot wire. The ceramic insulator is cemented into place before the slot is milled. A square recess, into which a microscope cover slip is placed, is milled in the stainless steel rotor F to a depth equal to the minimum thickness of the cover slip. Variations in cover slip thickness are cared for by means of the spring

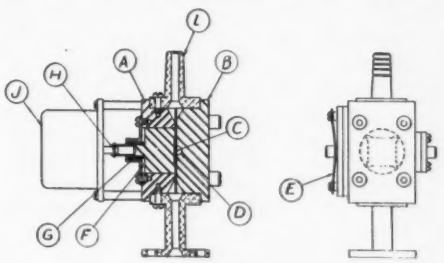

Fig. 1.
Thermal precipitator assembly.

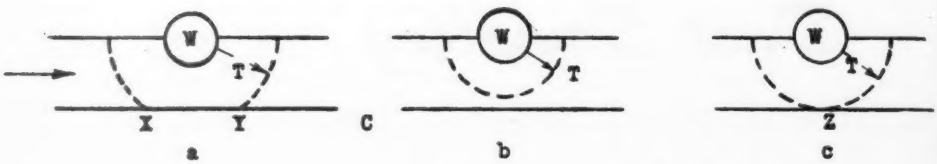

Fig. 2.
Result of variation of temperature gradient.

G, which keeps the surface of the cover slip against B at all times. The shaft of the rotor is slotted so that it may be driven by the cross pin H in the shaft of the 1 RPM synchronous motor J. The air sample. drawn through the instrument at the rate of approximately 10 $cm.^3$ per minute by means of a water displacement pump, enters through K, passes between the hot wire and the cover slip, and is discharged through L. The temperature of the wire is adjusted so that the dust free zone surrounding the hot wire is tangent to the collecting plate. At this temperature the most dense particle deposit is in the center of rotation of the cover slip. If the temperature is too low, then no particles will be deposited. If the temperature is too high, then a clear zone will be observed in the center of the slide, followed by a zone of maximum density. If W in Fig. 2-a represents the wire, C the cold surface, and T the thickness of the dust free space, then the dust in the air stream traveling in the direction shown will be deposited on a line at X. perpendicular to the surface of this paper. Should the collecting surface rotate, then a clear circle of diameter XY will appear on the surface. Under the conditions shown in Fig. 2-b, no dust will be collected. If the dust free space is as shown in Fig. 2-c, then the dust will precipitate along the line Z, directly under the hot wire. The proper temperature is attained when a 2.4 ampere alternating current is passed through the wire. The operating temperature is a function of the ambient temperature if the only avenue of heat loss is by radiation. The current is varied between 2.3 and 2.5 amperes as the ambient temperature changes from 65° F. to 90° F. The temperature of the instrument may be held constant by means of circulating water, as shown in Fig. 3. Due to the number of variables, proper operating temperature must be experimentally determined for each instrument.

The instrument may be used to take samples for examination with the electron microscope. To do this, a ⅛" diameter sintered Alnico magnet (purchased from Terry Sales Company, Maumee, Ohio) is placed in the center of the rotor, or at any other radius within one-half the width of the air channel from the center of the rotor. The grid with the collodion membrane on it is then placed on the end of the magnet, and the instrument used in the usual manner.

It should be noted in Fig. 4 that the dimension D on the rotor should be great enough so that dust particles will not be precipitated on the rotor. Dimension T should be great enough so that the electron microscope grid will not be knocked off during rotation.

To use the instrument, part B is re-

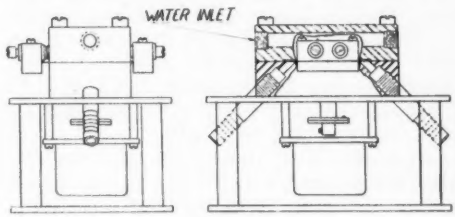

Fig. 3.
Water cooled thermal precipitator.

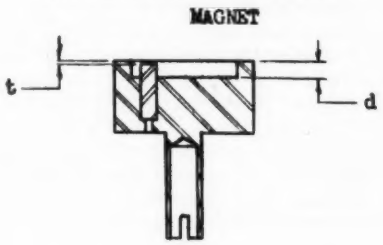

Fig. 4.
Rotor with magnet for electron microscope grid.

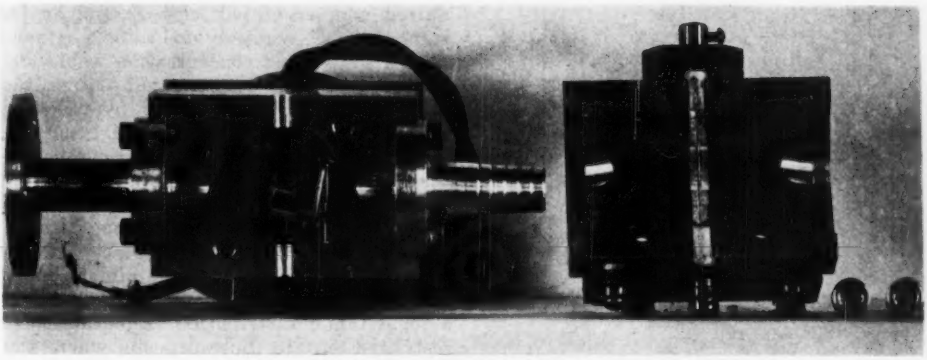

Fig. 5.
Thermal precipitator, showing rotor and hot wire.

moved, a cover slip is placed into the rotor F, and part B is replaced and fastened by means of thumbscrews. The synchronous motor, heater current, and water displacement pumps are then turned to take the sample. Figs. 5 and 6 are photographs of the thermal precipitator currently in use in this laboratory. The instrument is mounted directly on the dust chamber by means of flange K.

Dust Concentration Measurements

BECAUSE of the rotation of the collecting plate, the density of particle deposition decreases as the distance from the center of rotation increases. If the variation of the particle concentration with respect to radial distance is known, the total number of particles collected could be determined from a single count taken at some known distance from the center.

If the particle concentration ρ is uniform at a distance r from the center, then the number of particles, dN on the differential area dA is:

$$dN = \rho dA. \text{ However,}$$
$$\rho = f(r), \text{ and}$$
$$dA = 2\pi r dr$$
$$\therefore dN = f(r) \times 2\pi r dr$$
$$N = 2\pi \int_{r=o}^{r=R} f(r)\, r dr \qquad (1)$$

$f(r)$, determined by fitting the line in Fig. 7 by the method of least squares, is

$$\rho = Be^{-.141\, r}$$

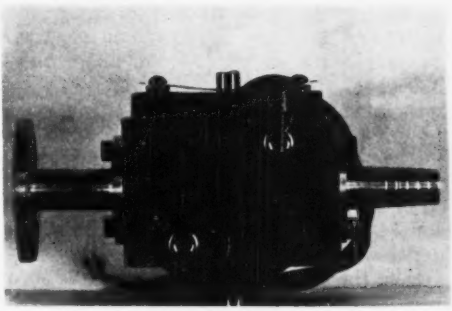

Fig. 6.
Assembled view of thermal precipitator.

$$\therefore N = 2\pi B \int_{r=o}^{r=R} e^{-.141^{r}} r dr \qquad (2)$$

Integrating, we get $N = .102\ \rho_0$, (3)

where ρ_0 = particle density, number of particles per cm.^{2} in the center. If particles are counted at any other distance from center, equation 2 may be solved for the particle concentration in the center, and the value thus obtained may be substituted into equation 3.

It should be noted that the measured particle density was corrected for "coincidence loss," or overlapping. The ratio of the number of particles counted to the number actually present, but not counted because of overlapping, is given by the formula of Irwin, Armitage, and Davies.[4]

$$\frac{N}{C} = -\left(\frac{A}{\pi cd^2}\right) \ln \left(1 - \frac{\pi cd^2}{A}\right)$$

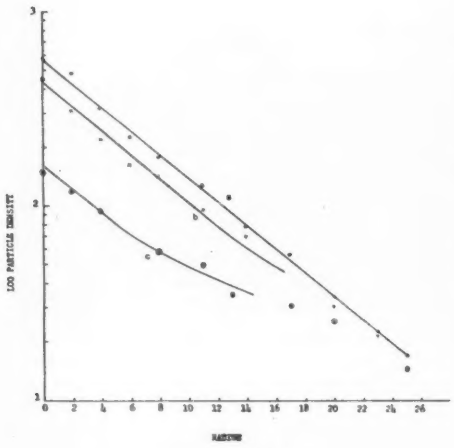

Fig. 7.
Particle density distribution curve.

N = number counted
C = true number
A = area covered by particles
d^2 = mean square diameter

The area over which the particles were counted was 4×10^{-4} cm.^{2} and the mean particle diameter was 1.25 microns.

From the curves of Fig. 7, it may be seen that the variation of particle density with respect to distance from the center is logarithmic over a radius of 0.5 centimeters only if the particle density exceeds about 10^7 particles per cm.^{2} in the center. At a sampling rate of 10 cm.^{3} per min., this corresponds to a 30 minute sample of air containing 87 million particles per cubic foot. Curve a represents a sample that meets this requirement. Curves b and c, which are asymptotic, have fewer than the required number of particles. Should an instrument be required to sample atmospheres whose dust concentration would dictate an unusually long sampling time, the precipitator may be modified by reducing the radius of the collecting plate. Since the initial slopes of the distribution curves are the same, a logarithmic distribution over the entire deposit may be achieved with fewer particles. It should be noted, however, that regardless of the diameter of the collecting plate, a certain minimum number of particles must be precipitated to have a logarithmic distribution. Equation 3 is restricted only to those deposits where the density distribution is logarithmic.

The existence of an asymptote is to be expected. The difference between the linear velocities of two points on radii (r) and $r + \triangle r$ is much greater if r is very small than if r is large. Since adjacent areas at relatively great distances from the center of rotation will be traveling at approximately equal linear velocities, the density of the deposit will approach an asymptotic value.

Summary

A THERMAL precipitator with a rotating collecting plate is described. As a result of the rotation, a deposit in which the particles are randomly distributed with respect to size is obtained. The instrument is small, mechanically simple, and easy to use.

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CONSULTATION and RESEARCH

AIR POLLUTION
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HYGIENE AND SAFETY SERVICE

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AND ASSOCIATES

Health Safety Considerations *in the disposal of radioactive wastes*

FORREST WESTERN, Ph.D., U.S. Atomic Energy Commission
Washington, D.C.

DURING the past eight years much has been said and written about the possible effects of the release of radioactive wastes into our environment. Spectacular accomplishments in the production and applications of atomic energy, together with the novelty of this field, have led to considerable speculation with wide differences of opinion as to the minimum quantities of discharged radioactive wastes which may be hazardous to individuals, to groups of individuals, or to life in general. It is inevitable that lack of over-all perspective should lead outstanding specialists in a number of related fields to exaggerated expressions of concern which have frequently made startling news stories.

We now have more than ten years experience in the handling of large quantities of radioactive materials under widely diverse conditions. During this period we have made extensive experimental studies of the behavior and biological effects of the more significant radioisotopes, both in laboratories and when released into the environment under selected conditions. These studies not only have failed to discover any unexpected biological or ecological hazards but are providing quantitative relationships upon which we can build increasingly realistic practices in the control of radioactive wastes with confidence in the margin of safety to public health which they afford. With the present trend toward a greatly expanded production and use of radioactive materials, it may be expected that during the next several years the routine control of radioactive wastes will become as commonplace to persons interested in problems of industrial and public health as is the control of many hundreds of other dangerous materials frequently involved in modern industrial operations.

The purpose of this discussion is to outline the general nature of the problem of ensuring health protection in radioactive waste disposal by indicating with necessary brevity some of the general considerations applicable to the determination of standards of limitation of human exposure to radioactive materials and some of the specific considerations which may arise in connection with local situations. However, it is not intended nor, indeed, is it considered practical to provide in a general discussion detailed answers to questions which depend upon local physical features.

Standards of Limitation of Human Exposure

MUCH OF OUR extensive experience with chronic exposure of man to radiation over long periods of time and at levels significantly above natural background has been of three sorts: (1) the incidental exposure of technical, scientific and professional personnel in connection with experimental, diagnostic and therapeutic use of x-rays; (2) similar exposure to the radiation from radium outside the body; and (3) exposure to radiation from radium more or less permanently fixed in the skeleton of the body. The first two categories of experience lead to the currently accepted recommendation that the maximum permissible rate of whole body exposure to x and gamma radiation of quantum energies below 3 Mev. shall be 0.3 roentgen per week, measured at the depth of the blood forming organs assumed to be at an average depth of 5 cm. from the surface of the body. The third category of experience leads to the recommendation that the maximum permissible skeletal content of radium shall be

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0.1 micrograms. It must not, however, be inferred that the sum total of our experience with the effects of radiation as it relates to human exposure can be characterized thus simply.

In the discussion of possible hazards due to the disposal of radioactive wastes, we are primarily interested in hazards resulting from radiations from radioactive materials which have been taken into the body as a result of their occurence in air, water or food supplies. However, since the biological data upon which maximum permissible levels of exposure to these materials are based are customarily based on either the value of 0.3 roentgen per week or the value of 0.1 microgram of radium in the skeleton, it is appropriate at this point to consider the applicability of these values of maximum permissible rate of exposure to the determination of standards for the discharge of radioactive wastes.

The above statements of recommended maximum permissible levels of exposure to radiation, either from sources external to the body or from radium within the body, set no limits on the length of time for which the exposure may be incurred at these rates. Because the experience upon which this recommendation is based is principally that of occupational exposure of healthy adults, we may assume that these levels are at least applicable to persons in good health through periods similar to those in which exposure has commonly been incurred for occupational reasons. However, since at higher rates of radiation exposure some of the effects of radiation depend upon the total exposure as well as upon the rate at which it is incurred, caution suggests that we inquire whether the margin of safety contained in these recommendations is maintained when they are applied to conditions in which the exposure may persist throughout the entire lives of persons living in the vicinity of some such operation as a nuclear power plant.

Our concern on this point is heightened by a number of considerations. The observable damage to rapidly growing tissues, as in young children and particularly at certain stages in the development of the fetus, occurs at lower dose levels than to more slowly growing tissues. The uptake of some chemical elements by body tissues also depends upon such factors as age and condition of health. It may be observed, too, that while few of the radioisotopes are of genetic concern from the point of view of internal dose, if one were concerned primarily with such radioelements as tritium, carbon, sodium and phosphorus, it should be recalled that the average cumulative genetic effects resulting from a constant rate of exposure from the beginning of life will be many times greater than if exposure is only incidental to occupation.

Some of the effects of exposure to radiation at *unsafe* levels occur only after periods of many years. It might follow that rates of exposure which have been judged from occupational experience to be safe may not be found to be so if the periods of exposure at these rates are lengthened to full lifetimes. This point of view is supported by the following argument. At higher rates of exposure, the occurrence of certain adverse effects of radiation has a probability which depends both upon the rate of exposure and upon the time that has elapsed since the exposure began. If the probability of such an effect were not reduced absolutely to zero at these recommended maximum permissible levels, it might be assumed on this basis alone that the probability of the ultimate occurrence of the effect in an individual would be increased by starting his exposure at an earlier age.

Maximum Permissible Body Content

IT IS INAPPROPRIATE to discuss here details of the determination of specific values of maximum permissible body content of various radioisotopes. These details are discussed in the report of the Subcommittee on Internal Dose of the National Committee on Radiation Protection, issued March 20 by the National Bureau of Standards as Handbook 52. This handbook gives recommended maximum permissible values of body content for each of some 70 radioisotopes of current interest. While certain factors involved in the derivation of these values undoubtedly give a larger average margin of safety than is involved in the basic maximum permissible levels from which they are derived, they are still subject to the question of whether or not they are *equally* appropriate for industrial ex-

posures and for lifetime environmental exposures.

In view of the considerations discussed above, until we are more certain as to how the effects of exposure to radiation at these low levels may depend upon the age of the individual at the time the exposure is begun, it appears appropriate to use lower maximum permissible values of body content of the various radioisotopes for lifetime environmental exposure than for industrial exposure. While there is little direct quantitative evidence upon which to base a differential factor, the general nature of the conditions involved suggests the use of an uncertainty factor in the range of from 3 to 10. Since it may be assumed that any respective values of maximum permissible levels used for these two purposes will be subjected to continuous scrutiny, either of them or the ratio between them should be readily subject to increase or decrease as justification for such changes may become apparent.

Application to Release of Wastes

IN CONSIDERING the extent to which standards of radiation protection based on industrial experience may not be applicable to lifetime environmental exposures, we are concerned with radiation dosage rates from radioactive materials within the body, and, consequently, with the body content of such materials which would produce these dosage rates. From the point of view of one whose interest is that of limiting the release of radioactive materials to safe values, the question of immediate interest is this: At what rates or in what quantities can these materials be released without resulting in their accumulation in excessive quantities in the bodies of persons living or working in areas affected by their release? This question naturally divides itself into two phases: (1) at what rates can these materials be taken into the body without their accumulation in the body ultimately exceeding the maximum permissible body content; and (2) how are the rates of release or quantities released related to the quantities appearing in the air, water, or food supplies of any person or group of persons?

Whether or not the first of these two questions is simpler than the second, it is more readily disposed of here because of the extensive work on this subject by the Subcommittee on Internal Dose of the National Committee on Radiation Protection. In National Bureau of Standards Handbook 52 the Committee has given as maximum permissible concentrations in air and water, of the radioisotopes covered by its recommendations, those concentrations estimated to result in maximum permissible values of body content if the air or water in question is used continuously as a sole source of supply. While the recommendations of Handbook 52 do not specifically cover the occurrence of these radioisotopes in food supplies, they may readily be extended to include this case by assuming that the maximum permissible rate of intake* into the digestive system is independent of whether or not the material occurs in the water supply or in food.

In the application of the maximum permissible concentrations recommended in Handbook 52, it may be observed that within appropriate limits one is interested in average rates of intake rather than in transient values. The length of the period of time over which averages can be taken without exceeding maximum permissible values of body content depends upon the ratio of the average rate of intake to the maximum permissible constant rate and upon the effective half-life** in the body of the particular radioisotope involved. In any event, comparison with current practice in limitation of exposures to radiation from external sources suggests that the periods over which rates of intake are averaged need not be less than one week.

The determination of relationships between concentrations and quantities of radioactive materials released into the environs and the probable resultant occurrence of these materials in air, water, or food supplies will require the evaluation of factors which may differ greatly from one case to another. These factors may include the manner in which the material is released; location of points of release; rel-

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*From the assumptions made in NBS Handbook 52, the maximum permissible rate of intake of a radioisotope into the digestive system, measured in microcuries per day, is 2300 times the maximum permissible concentration in water, measured in microcuries per milliliter.

**The term effective half-life is defined in Handbook 52, and values for particular radioisotopes are given in Table 4, Column 8.

ative locations of air and water supplies for residential, industrial, or agricultural areas; and the various physical features of the area in which the release occurs. Physical features of frequent interest include the characteristics of soils and their substrata and of local geology, hydrology, and meteorology. The evaluation of factors which, in the case under consideration, may be critical should be performed by specialists in their study and interpretation.

Disposal into Flowing Streams

THE TYPE of release of radioactive materials for which estimates of maximum permissible rates of release can be most readily made is that of water-borne wastes into a flowing stream. Where mixing is sufficiently good that the average concentration of radioactive materials in the water drawn from the stream is equal to their average concentration in the stream, a knowledge of the volume rate of flow of water at the point of withdrawal enables one to estimate the highest average concentration to be expected in the water supply. Actual concentrations may be much less due to the removal of activity from the water by silting and by water treatment processes. From the point of view of public health, an important characteristic of this type of release is that the points at which the radioactive material can appear in water and food supplies are readily determined and estimated concentrations are subject to verification and revision.

An obvious factor of possible concern is the occurrence of radioactive materials in fish used for food. As in nearly all of the problems involved in the release of radioactive wastes, evaluation of this factor must be made on the basis of local conditions. Although some of the organisms in the food chains of fish may concentrate certain radioisotopes by very high factors, in general the over-all factors of concentration in fish are not high. Exceptions occur with some radioisotopes, especially in cases in which the radioisotope happens to be of an essential chemical element in which the water is deficient. Variations also occur with different kinds of fish. Concentrations of some radioelements occur principally in scales, bones, or other organs not used for food. Evaluation of the importance of the occurrence of radioactive materials in fish is not complete until an estimate is made of the maximum resultant rate of intake of these materials by any person.

Disposal into the Atmosphere

THE PROBLEM of the determination of safe rates of release of radioactive materials into the atmosphere has much in common with that of determining safe rates of release into flowing streams. Average concentrations at points at which the air is first available for breathing will depend upon distance, upon the altitude at which release occurs, and upon average meteorological conditions. As in the case of release into streams, the points at which the material can appear in air and food supplies are readily determined and estimated concentrations are subject to verification. It should be noted that under certain circumstances, the safe rate of discharge of a particular radioisotope into the atmosphere may be limited by its deposition on vegetation used for food or feed rather than by concentrations in air at accessible points.

Discharge into Sanitary Sewers

FOR MANY laboratories, hospitals, and other operations using radioisotopes, the most convenient method of disposal of such materials in solution is to discharge them into the sanitary sewer system. Small experimental animals may be discharged into the sewer system through the use of mechanical blenders. In a great many cases, the quantities of radioactivity involved will be so small that a cursory examination will disclose that no hazard is involved. The National Committee on Radiation Protection presents in National Bureau of Standards Handbook 49 recommendations to hospitals for disposal in sewers of radioative iodine and radioactive phosphorus.

In cases in which the quantities of radioactivity involved are sufficiently large to require careful study, in addition to the considerations which apply generally to the discharge of radioactive materials into running streams, safe rates of discharge into sewer systems may conceivably be limited by the accumulation of the radioactivity in sludge used for the fertilization of crops. Where sewer systems discharge into the earth through lagoons or similar

devices, the quantities of radioactive material which may safely be discharged into the sewer may be limited either by the concentrations of radioactive material which will occur in the vicinity of the point of discharge or by the resultant concentrations which may occur in ground waters.

Disposal into the Earth

CONSIDERATION of the conditions under which radioactive materials may safely be released into the earth may arise for various reasons. In some locations there are no continuous surface streams and in these, discharged process waters, together with any residual radioactivity which they may carry, are in effect discharged into the earth. Some types of operation result in the contamination of equipment and other materials with quantities of radioactivity which make disposition of the material difficult. Under conditions in which these can be buried without hazard, this method of disposal may offer distinct advantages.

In the operation of reactors at high power levels, radioactive wastes are produced at rates greater than those at which they can be released into water or air. Large fractions of such wastes may be separated from process fluids and concentrated for retention. Under some conditions one is interested in the possibility of releasing such material into the earth, either intentionally or accidentally.

The principal hazard likely to be associated with the burial of relatively small quantities of radioactive materials is that they will be accidentally recovered under hazardous conditions. For large quantities of material the hazard lies in the possibility that the radioactivity will find its way into water supplies in dangerous concentrations. In some cases, the physical structure of the overburden of soil, the rate of migration and the rate of radioactive decay of the radioisotopes involved, the depth of the water table and flow of the ground water are of such a nature as to preclude any significant hazard. In other cases, unfavorable characteristics of one or all of these factors may prohibit burial* or other release into the earth. Fortunately, many of the radioisotopes of which maximum permissible rates of intake into the body are low either have short half-lives or migrate very slowly through common soils, or both.

*The term burial as used here does not include underground storage in drums, tanks, or other impervious containers.

Disposal into the Oceans

THE LEAST hazardous place to bury radioactive wastes appears to be in the oceans, beyond the continental shelf. If materials are packaged in such a manner as to ensure their reaching the bottom at depths of the order of a thousand fathoms or more, the physical and biological processes by which they can diffuse outward and upward after disintegration of the package are of such a nature that it may be expected that tremendous quantities of radioactive material would be required to produce any detectable increase in the radioactivity of water or ocean life near the surface. At the present time, disposal by this method appears to be limited only by the cost of packaging to meet the requirements of safe handling and by the cost of transportation.

Summary and Conclusion

THE EXTENT to which a radioisotope may safely be released into the natural environment depends upon the rate of intake, averaged over appropriate periods of time, of the radioisotope by persons working or living in the affected area. Under many conditions, large quantities of a radioactive material may be released with certainty that resultant rates of intake will be far less than maximum permissible values.

Release under conditions in which average resultant concentrations in air, water and food supplies may not be readily measurable or are not subject to continuous control will, in general, require either a higher degree of confidence in original estimates of safe quantities or application of a larger margin of safety.

The ranges of quantities of material, rates of release, or concentrations at the point of release which will be safe under various sets of conditions are so wide that it is impossible to determine realistic upper limits except by evaluation of the conditions which actually exist in any particular case. Health safety standards should, in all cases, be based upon resultant rates of human intake rather than upon arbitrary limitation of quantities released.

SPECIFICATIONS FOR CALCULATING

The Median Effective Dose

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THE DETERMINATION and calculation of quantal (all-or-none) response is of importance in many fields. Whenever the measurement of the reaction to any stimulus, be it physical, chemical or biological, is expressed, quantitation becomes necessary. For toxicological studies the response measured is death; in the evaluation of insecticides it may be death or knock-down, while in the assay of drug potency it may be prevention of death. The test subjects of all biological assays exhibit extreme variability in response and for this reason large numbers of animals are usually tested to estimate the median-effective amount of the agent under examination.

In animal tests practical considerations dictate that the operation be performed with the maximum economy consistent with accuracy of results. The limiting factors are: cage space, the cost of animals, the time required for the care, dosing and observation of large numbers of animals, and the necessity of testing numerous materials. Therefore, the most precise and economical methods have been sought that would allow an accurate estimation of the median-effective dose (ED_{50} or LD_{50}). Specifications of this type cannot be based on mere opinion or educated guess—they must be derived by statistical evaluation of experiments designed to determine their validity.

The data presented here and used to establish the requirements for an accurate economical estimation of the ED_{50} are an outgrowth of such an effort of the Chemical Hygiene Fellowship at Mellon Institute of Industrial Research. They are based on single oral or single percutaneous applications of chemicals to rats and rabbits. The animals were observed for 14 days after dosing and those that died were autopsied to expose extraneous causes of death. The individual make-up of each set of experiments will be discussed briefly under the following categories: number of animals dosed, sex differences, ratio between successive dosage levels, estimation of a fiducial range and the method of calculation of the ED_{50}.

Number of Animals Dosed

TO DETERMINE the effect of the number of animals used per dosage level on the calculated value of the LD_{50}, rats that weighed between 90 and 120 gms. were dosed with a 10% aqueous dispersion of an insecticide. A summary of the results is presented in Table I. The ratio between successive dosage levels and the range is given for later discussion. As mortality is the response measured, all median-effective dose levels are henceforth denoted as LD_{50}s or more explicitly the lethal dosage for 50% of the animals treated.

The prime purpose of this type of single-dose experiment is to determine as accurately as possible the toxicity of a chemical. The measure most often used to express this dosage is the median-effective dose or LD_{50}. It may be seen from Table I that, for practical purposes, the LD_{50} values were almost identical using 3, 4, 5, 6, 7, 8, 9, or 10 animals per level when the ratio between dosage levels was 1.26. The same is substantially true for a ratio of 2.0 when 3, 4, 5, or 6 rats were dosed per level.

In this laboratory a distinction used to be made between the so-called advanced and range-finding single oral toxicity test name-

TABLE I.
RESULTS OF VARYING RATIO BETWEEN DOSAGE LEVELS AND THE NUMBER OF RATS PER LEVEL

Animals per Level	Ratio Between Levels	LD_{50}	1.96σLD_{50} Range	Range in Gm./kg
5	5.0	5.59	—	—
5	2.0	3.73	(2.68 to 5.21)	2.53
5	1.28	3.77	(3.03 to 4.69)	1.66
5	1.26	4.07	(3.33 to 4.98)	1.65
3	2.0	4.49	(2.86 to 7.06)	4.20
4	2.0	4.00	(2.85 to 5.61)	2.76
5	2.0	3.73	(2.68 to 5.21)	2.53
6	2.0	3.56	(2.68 to 4.74)	2.06
3	1.26	4.03	(3.25 to 4.98)	1.73
4	1.26	4.21	(3.55 to 5.00)	1.45
5	1.26	4.07	(3.33 to 4.98)	1.65
6	1.26	3.90	(3.30 to 4.61)	1.31
7	1.26	3.92	(3.38 to 4.55)	1.17
8	1.26	3.86	(3.40 to 4.40)	1.00
9	1.26	3.82	(3.41 to 4.29)	0.88
10	1.26	3.80	(3.43 to 4.40)	0.77

TABLE II.
ADVANCED VS. RANGE-FINDING LD_{50}

Advanced	Range Finding	Advanced	Range Finding
0.52	0.56	4.36	4.07
1.67	1.86	5.10	5.12
1.93	2.07	5.35	5.62
2.08	2.13	5.70	5.21
2.58	2.30	5.84	5.78
2.59	2.30	6.31	5.98
2.86	2.70	6.63	7.06
2.91	2.96	7.15	6.74
3.10	2.96	7.53	8.65
3.34	2.58	8.47	8.16
3.98	4.07	9.43	8.90
4.17	3.46	10.60	10.24

ly: the former when 10 animals were dosed per level at a ratio of 1.26 between levels and range-finding (R.F) when five animals were dosed using a ratio of 1.26 or 2.0. In 1950 the advanced (Adv.) LD_{50}s of 24 materials calculated by the use of probits were compared with the R.F. value that would have been calculated if the mortality ratio for the first five animals dosed per level had been used. The latter calculation was made by the method of moving averages. The values are presented in Table II.

The mean Adv. LD_{50} is 4.76 while that of the R.F. is 4.64. The relationship between the two series of values, as calculated by the correlation coefficient, is + 0.988 where 1.0 is perfect correlation. The equation of best fit, calculated by the method of least squares, is $Y = 0.1718 + 0.9876X$ where Y is the Adv. and X is the R.F. LD_{50}. The standard error of estimate of Y from X is 0.3912.

The data summarized in Table II indicate that five animals are practically as good as 10 to determine the LD_{50}. On comparatively inexpensive animals, such as rats, this reduction is sufficient. However, on larger animals, such as rabbits, substantial reduction in cost would result if fewer than five animals per level were justified on the basis of accuracy. Therefore, the LD_{50} values obtained from single percutaneous dosing of five rabbits per dosage level were compared with those which would have been obtained if only the first four of the five per level had been dosed. The results are presented in Table III.

The mean LD_{50} values using five rabbits per level is 3.17; that with four per level is 3.03. The coefficient of correlation between the LD_{50}s calculated using four or five animals per level is + 0.977. This is definitely significant of the positive relationship between the values. Therefore, to determine the LD_{50} with reasonable confidence in its accuracy the use of either four or five animals per dosage level is sufficient.

Sex Differences

TO ASCERTAIN whether sex differences played an important role in determining LD_{50}s, a review of a study of 38 compounds where both sexes had been dosed was carried out. The LD_{50}s that resulted when five animals of each sex were dosed at each

TABLE III.
LD_{50} VALUES USING FOUR OR FIVE RABBITS PER DOSAGE LEVEL IN THE SKIN-PENETRATION TEST

n = 4	n = 5	n = 4	n = 5	n = 4	n = 5	n = 4	n = 5
0.25	0.31	0.63	0.59	1.50	1.78	4.76	4.36
0.30	0.31	0.64	0.55	1.68	1.87	5.31	5.90
0.30	0.36	0.64	0.65	2.52	2.24	7.13	5.66
0.36	0.41	0.71	0.62	2.83	3.25	7.13	8.19
0.40	0.43	0.85	0.82	3.00	3.10	10.00	12.31
0.42	0.54	1.06	1.09	3.00	3.56	10.00	12.31
0.48	0.43	1.13	1.23	3.56	3.56	14.14	12.31

TABLE IV.
LD_{50} VALUES WHEN FIVE RATS WERE DOSED PER LEVEL
(ratio = 1.26)

Male	Female	Male	Female	Male	Female
0.04	0.05	3.84	3.66	8.68	11.26
0.10	0.10	4.29	2.46	10.30	8.24
0.18	0.18	4.29	2.59	11.26	9.80
0.77	1.04	4.67	4.87	11.26	11.26
1.48	1.48	5.66	4.36	15.40	18.64
1.54	1.41	6.13	6.64	17.04	22.48
1.83	1.41	6.48	6.16	17.04	29.67
2.24	1.62	6.50	4.92	19.57	9.80
2.46	1.87	6.50	6.50	23.00	9.30
2.46	3.76	6.50	9.80	25.90	17.00
2.58	2.30	7.06	7.27	26.20	26.20
2.59	2.46	7.27	5.62	74.00	81.60
3.10	2.45	7.46	7.46		

level are given in Table IV. The only element under control that differed in this study was sex; in all instances the number dosed per level and the ratio between dosage levels was constant (1.26). Rats of the same stock, age and weight were used for each material.

The coefficient of correlation of the LD_{50}s for males versus females is + 0.955 indicating a significant relationship. This being true, it then became possible to add to these 38 cases 105 additional instances where males were dosed on levels that differed by a ratio of 1.26 and females on dosage levels that differed by a ratio of 2.00. These additional values are presented in Table V.

The coefficient of correlation of the LD_{50}s of the 143 materials of Table IV and V is + 0.961. The mean of the LD_{50}s for the males is 8.36 and for females 8.96 gm./kg. The best fit line for the 143 pairs of points is $Y = 0.3149 + 0.8983X$ where Y is the LD_{50} for females and X = the LD_{50} for males.

The standard error of estimate of Y from X is 3.45 which is too high to allow the use of one value to determine the other LD_{50}. This is true largely because the values of the LD_{50}s included in this comparison range from less than 0.1 to almost 100 gm./kg. As the standard error of estimate is the standard deviation (S_y) times $\sqrt{1 - r^2}$ (r = the correlation coefficient), the S_y is the factor that is necessarily large when the range of LD_{50} values is large. To reduce this, subdivision of these data could be made so the range would be smaller, thus lowering the standard deviation. These relationships are presented in Table VI.

When the $1.96\sigma LD_{50}$ ranges of these 143 pairs of values are compared, only eight of those of the males did not include the range of the $1.96\sigma LD_{50}$ of the females. In other words, 135 of the 143 indicated that

TABLE V.
LD_{50} VALUES WHEN FIVE RATS WERE DOSED PER LEVEL
(ratio = 1.26 for males; 2.00 for females)

Male	Female	Male	Female	Male	Female	Male	Female
0.14	0.14	2.04	2.46	3.84	4.92	8.16	6.50
0.19	0.20	2.17	2.46	3.88	4.29	8.16	11.26
0.42	0.82	2.34	2.14	3.90	3.25	8.24	7.12
0.46	0.54	2.43	3.08	3.90	4.36	9.16	9.80
0.67	0.47	2.58	2.46	4.07	4.92	9.61	10.32
0.73	0.55	2.59	2.83	4.09	5.65	9.70	11.26
0.73	0.57	2.70	1.87	4.13	2.59	10.30	9.80
0.77	0.71	2.74	1.87	4.59	5.66	10.40	11.26
0.96	1.41	2.74	2.83	4.73	3.73	11.23	11.26
1.07	1.41	2.74	2.83	4.89	2.83	12.12	11.26
1.12	0.94	2.82	1.19	4.89	4.29	13.70	9.80
1.22	1.35	2.82	1.78	5.16	4.29	14.13	12.93
1.29	1.09	2.82	2.83	5.37	3.73	14.80	14.10
1.31	1.30	2.96	1.78	5.46	3.25	20.40	22.50
1.33	0.78	2.91	2.46	5.62	4.94	20.50	28.30
1.35	0.94	2.91	2.46	6.13	4.29	28.25	29.67
1.48	0.82	2.96	4.29	6.13	7.46	28.30	28.30
1.48	2.82	3.08	3.73	6.16	5.66	29.10	25.80
1.63	1.23	3.25	3.25	6.48	6.50	29.58	38.90
1.70	1.62	3.25	4.29	6.48	8.53	31.00	28.30
1.78	1.41	3.26	2.14	6.75	4.29	32.50	30.80
1.78	1.87	3.26	2.83	6.86	4.92	34.00	28.30
1.78	2.59	3.40	1.83	7.06	4.92	38.80	34.50
1.86	2.14	3.40	2.59	7.40	7.46	47.30	22.50
1.95	1.41	3.46	4.29	7.40	9.80	48.70	44.70
2.04	1.23	3.84	3.73	8.12	5.66	51.60	33.90
						93.20	81.90

TABLE VI.
RELATIONSHIP BETWEEN THE RANGE OF LD_{50} AND THE VARIANCE IN THE COMPARISON OF THE LD_{50} OF FEMALE (Y) TO MALE RATS (X)

No. of Pairs of Values	Range in LD_{50}s of Males	Correlation Coefficient	Standard Deviation of Y	Standard Error of Estimate of Y	Best Fit Line; Y =
128	0.04 to 93.2	+ 0.963	12.46	3.36	0.2354 + 0.9143X
13	0.04 to 0.96	+ 0.862	0.40	0.20	1.1047X − 0.0019
61	1.07 to 4.89	+ 0.735	1.20	0.82	0.4500 + 0.8515X
28	5.46 to 9.70	+ 0.705	2.36	1.66	1.4271X − 0.3179
26	10.3 to 93.2	+ 0.928	19.67	7.33	0.9015X + 0.7658

the values for the male and female LD_{50} were similar. This is 94.4% when one would theoretically expect 95% — remarkable agreement with theory. It may be concluded that in the data analyzed there is no reason to calculate the LD_{50} for males and females separately. One or the other is a good enough estimate of the toxicity of a chemical. Only once in 20 times did a chemical tested differ in toxicity between males and females. It should be mentioned that the experience in this laboratory is not complete proof that the same situation would hold for all compounds. Most of the chemicals tested were aliphatic organic chemicals. Whether the same relationship would hold if most of the compounds were aromatic amines, for example, could be determined only by actual comparison. Furthermore, it is known that some chemicals have specific actions which cause a marked sex difference in toxicity.

Ratio Between Dosage Levels

AS INDICATED in Table I and definitely shown in Table V, either 1.26 or 2.00 is a satisfactory ratio between successive dosage levels for the calculation of the LD_{50}. A value much larger than 2.0 gives an inaccurate result, e.g., 5.0 in Table I. In general as this ratio is decreased more animals will be needed to find the four dosage levels that surround the LD_{50}. One can guess at the first two dosage levels to try with a new chemical by finding previous information on the LD_{50} of a chemical of similar structure. If these levels are far enough apart, at least one of them will be included in the actual calculation of the LD_{50}. But for the economical LD_{50} calculation on the evidence presented in Table V the ratio of 2.00 appears to be the most satisfactory.

Another consideration must enter in the final answer to the question of the number of animals to dose and the ratio between dosage levels. The best estimate of the mean of the general population of a variable is the mean of a sample of that population. Consequently, any accurate method of calculation of the midpoint of a sample, here the LD_{50}, will be satisfactory if enough animals are dosed on levels not too far apart that encompass the value of the midpoint. Up to this point it has been concluded that four or five animals per dosage level with levels differing by a ratio of 2.0 are satisfactory qualifications for this calculation. However, the number of animals per dosage level and the ratio between levels both affect the fiducial range, often calculated as 1.96 times the standard deviation of the LD_{50} ($1.96\sigma\ LD_{50}$).

This $1.96\sigma LD_{50}$ theoretically encompasses the values within which the LD_{50} would be expected to lie 19 times in 20 (if animals from the same colony of the same stock were dosed in an identical manner with the same chemical). As emphasized by Finney[2] although only one standard error (orσ) may be assessable from a particular set of data, the "temptation to regard a percentage effective dose estimated from one sample of subjects, whether animal or human, as a 'normal value' typical of the species, must not be bolstered up with the argument from a standard error based on the internal variation of the sample." In addition he states that the $LD_{50} \pm$ its σ is not an estimate of a "normal value" for the species under test, but is necessarily only an indication of what might be found in repeated tests of the same stock of this species under the same conditions of test in the same laboratory.

The LD_{50}, according to Finney, may have one standard error between determinations by one worker, another standard error be-

TABLE VII.
RELATIONSHIP OF THE LOGARITHM OR ANTILOG OF THE STANDARD DEVIATION OF THE LD_{50} TO THE NUMBER OF ANIMALS DOSED PER LEVEL

n	$100\left(\frac{\text{Log}\sigma \text{ For n } LD_{50}}{\text{Log}\sigma \text{ For n}=10 \text{ } LD_{50}}\right)$	$100\left(\frac{\text{Log}\sigma \text{ For n } LD_{50}}{\text{Log}\sigma \text{ For n}=5 \text{ } LD_{50}}\right)$	Antilog or gm./kg. Basis of Col. 2	Antilog or gm./kg. Basis of Col. 3
2	300	200	212	176
3	212	141	152	126
4	173	115	132	109
5	150	100	121	100
6	134	90	114	94
7	122	82	109	90
8	113	76	105	87
9	106	71	102	85
10	100	67	100	83

tween workers using the same apparatus and stock of animals in one laboratory, and yet another between determinations in different laboratories. Comparison of estimates obtained from several experiments by one worker, or in one laboratory will assess only the variations to be expected from day to day under those conditions and will not be related to variations between laboratories or between different stocks of test subjects. However extensive the experimentation on one population, no statistical analysis can demonstrate the applicability of the conclusions to a different population.

With the foregoing in mind, a discussion of the effect of the number of animals dosed per level and of the ratio between levels of dosage on the standard error (or the 1.96σ LD_{50}) will be presented. The formula for this calculation, using the method of moving averages as presented by Thompson[3] follows:

$$\log LD_{50} = \frac{d}{r_b - r_a} \cdot \frac{\sqrt{(1-f)^2 \cdot r_a s_a + r_{c+1} s_{c+1} + \ldots . f^2 \cdot r_b s_b}}{n-1}$$

The r and s values are mortality and survival numbers and may be assumed, for this consideration, to be constant ratios. For example, if four animals were dosed per level and 0 of 4, 0 of 4, 2 of 4, and 4 of 4 died on four successive levels, we assume that if eight were dosed on the same levels, 0 of 8, 0 of 8, 4 of 8, and 8 of 8 would die. Therefore, using this assumption, the only variables that remain are d—the logarithm of the ratio between dosage levels, and n—the number of animals dosed per level. Table VII indicates the relative size of the logarithm of σLD_{50} if d is held constant and n is varied from two to 10.

Viewing Table VII one may find additional reasons for not using two or three animals per dosage level. However, the logarithm of the standard deviation of the LD_{50} is only 50% higher using five animals per level than it would be using 10 while on the basis of antilog of these values the former is 21% higher than the latter (considering n = 10 to equal 100%).

If n, on the other hand, is held constant for each of the successive dosage levels, and the mortality ratios are again assumed constant the value of $1.96\sigma LD_{50}$ depends entirely on d. Therefore, if the ratio between dosage levels is 1.26 or 2.00, d would equal 0.1 or 0.30103 and the logarithm of σLD_{50} would be 3.0103 times as large in the latter case as in the former. To indicate the agreement of observation with theory in this assumption, the values obtained for the logarithms of the $1.96\sigma LD_{50}$s on 74 chemicals where animals were dosed at levels that differed by a factor of 1.26 or 2.00 are presented in Table VIII.

The mean ratio obtained by dividing the logarithm of $1.96\sigma LD_{50}$ using a ratio of 2.00 by the logarithm obtained by using the ratio of 1.26 between dosage levels is 2.45 for these 74 materials. Theoretically, it should be 3.0103. This is an appreciable deviation from theoretical, considering the size of the sample. The dispersion of the ratios is quite large as is indicated by a standard deviation of 1.22. Therefore, as the standard deviation is not accurately related to the toxicity of a chemical and as the prime consideration in a single-dose toxicity study is the determination of the

TABLE VIII.
STANDARD DEVIATION VALUES OF 74 CHEMICALS TESTED
BY USING BOTH RATIOS OF 1.26 AND 2.00

Log d ($1.96\sigma_{LD_{50}}$)			Log d ($1.96\sigma_{LD_{50}}$)			Log d ($1.96\sigma_{LD_{50}}$)		
d = 0.1 A	d = 0.30103 B	B/A	d = 0.1 A	d = 0.30103 B	B/A	d = 0.1 A	d = 0.30103 B	B/A
0.03062	0.11800	3.85	0.06511	0.18658	2.87	0.07661	0.11800	1.54
0.03920	0.11800	3.01	0.06511	0.19600	3.01	0.07661	0.14452	1.89
0.03920	0.14452	3.69	0.06511	0.19600	3.01	0.07772	0.14452	1.86
0.03920	0.14452	3.69	0.06198	0.11800	1.90	0.07772	0.11800	1.52
0.03920	0.14452	3.69	0.06198	0.11800	1.90	0.08684	0.11800	1.36
0.03920	0.14452	3.69	0.06198	0.11800	1.90	0.08684	0.11800	1.36
0.03920	0.14452	3.69	0.06198	0.11800	1.90	0.08855	0.11800	1.33
0.03920	0.16688	4.26	0.06198	0.14452	2.33	0.08855	0.14452	1.63
0.03920	0.18658	4.76	0.06198	0.18658	3.01	0.09023	0.11800	1.31
0.03920	0.18658	4.76	0.06198	0.18658	3.01	0.09023	0.11800	1.31
0.04620	0.09219	2.00	0.06198	0.19600	3.16	0.09023	0.11800	1.31
0.04801	0.11800	2.46	0.06198	0.40058	6.46	0.09023	0.14452	1.60
0.04801	0.11800	2.46	0.06790	0.11800	1.74	0.09508	0.14452	1.52
0.04801	0.14452	3.01	0.06790	0.11800	1.74	0.09508	0.18658	1.96
0.04801	0.14452	3.01	0.06790	0.11800	1.74	0.10330	0.58306	5.64
0.04801	0.15754	3.28	0.06790	0.14452	2.13	0.11394	0.15754	1.38
0.04801	0.16688	3.48	0.06790	0.14452	2.13	0.11728	0.09219	0.79
0.04801	0.19600	4.08	0.06790	0.16688	2.46	0.11728	0.16688	1.42
0.05233	0.22807	4.36	0.06790	0.39539	5.82	0.12605	0.11800	0.94
0.05544	0.11800	2.13	0.07576	0.11800	1.56	0.13134	0.11800	0.90
0.06032	0.18658	3.09	0.07576	0.11800	1.56	0.13134	0.27161	2.07
0.06198	0.14452	2.33	0.07576	0.14452	1.91	0.17920	0.23970	1.34
0.06511	0.09219	1.42	0.07576	0.14452	1.91	0.19213	0.14452	0.75
0.06511	0.11800	1.81	0.07576	0.14452	1.91	0.19369	0.11800	0.61
0.06511	0.14452	2.22	0.07576	0.20073	2.65			

LD_{50}; the qualifications of number of animals and ratio between dosage levels satisfactory to an LD_{50} calculation will suffice to give a reasonably accurate estimate of the LD_{50} and of its range. The assumption that the mortality ratios would be constant if different n's or d's were used is the crux of the discussion in the first part of this section. There is so much variation between animals being dosed, the techniques of various experimenters, the conditions at the time of dosing and other sources of error that the reduction in σ by using the largest n and the smallest d that is practical is unnecessary. These sources of variations are the factors that largely determine the σ.

Method of Calculation of ED_{50} or LD_{50}

MUCH HAS BEEN written comparing various methods of calculation of the ED_{50}. The moving-average method first proposed by Thompson[3] allows one to calculate the LD_{50} by interpolation using four consecutive dosage levels (K = 3) without any assumption that the data fit or must be transformed to any type of curve. The LD_{50} and its fiducial limit values obtained by this method agree very closely with those obtained by more complex and time-consuming methods such as the Bliss[1] calculation using probits (e.g., see Table II). Most of the simplifications of calculation proposed by others give a fair estimate of the mid-point but do not allow any estimation of the standard deviation. The time required to use these simplifications or to graph these data is still considerable compared to that necessary to calculate accurately the LD_{50} and its σ when the tables by Thompson and Weil[4] and Weil[5] for the moving-average method are used. It is more reasonable to interpolate in this simple manner than to use one transformation or another to give an estimate based on the theoretical assumption that the transformation changed the dosage-mortality ratios of the small numbers of animals dosed to a certain form of a curve. The use of the probit method has another drawback in that fairly large numbers of animals must be dosed on levels close to the LD_{50} to obtain a χ^2 that indicates a suitable fit to the data. This means that by the method of probits one could not calculate an LD_{50} using five animals per dosage level that differed by a geometric factor of 2.0.

Because of the ease of calculation of the LD_{50} and its σ using 2, 3, 4, 5, 6 and 10 ani-

mals per level by the use of tables of moving averages it becomes obvious that graphical or other approximate methods are hard to justify.

It is unrealistic to estimate the approximate value when a more accurate estimate can be calculated from the same data or by dosing only a few more animals. Using the method of moving averages with n = 5, K =3 d = 0.30103, most of the time it is necessary to dose only 20 rats to determine the LD_{50} for this species. If the cost of the animals justifies a reduction in this number, fewer animals per dosage level could be used (down to n = 2) and still the LD_{50} could be calculated statistically with useful accuracy.

Summary

THE FOLLOWING specifications are proposed for determination of the median-effective dose in a practical and economical test. These requirements were derived from data obtained in single dose oral and skin penetration studies made on hundreds of chemicals over a period of years by the Mellon Institute Chemical Hygiene Fellowship.

1. Either four or five animals per dosage level may be used but keep the number constant for each of the successive levels that surround the eD_{50}.

2. Four dosage levels separated by a geometric ratio of 2.0 are recommended.

3. Use the tables by Weil[5] for the moving-average method of calculation of the eD_{50}.

4. Either male or female animals may be used for single-dose toxicity tests as marked sex differences in reaction are seldom encountered.

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5. WEIL, C. S.: Tables for Convenient Calculation of Median-Effective Dose (LD_{50} or ED_{50}) and Instructions in Their Use. *Biometrics*, 8:249, 1952.

A Beryllium Case Registry

A MAN-MADE illness of considerable interest has been reported in the medical literature in this country since 1943 under various titles, in general referring to its association with exposure to certain beryllium compounds. As the years go by, more cases continue to appear from a variety of industrial and research operations using beryllium compounds. With funds supplied by the Atomic Energy Commission, it is planned to develop a beryllium case registry at the Massachusetts General Hospital in Boston. The purpose is to enable a study of the epidemiology of this disease, an evaluation of the beryllium hazard of incriminated operations, and dissemination of knowledge of the clinical course of beryllium poisoning especially in relationship to its medical management. The material collected is to be available for study and from time to time data will be sent to participating physicians summarizing facts that have been established. This description is published in the hope that physicians, roentgenologists, and pathologists, who have knowledge of cases of beryllium poisoning, will participate in making this beryllium case registry complete. Facilities and funds are available for prompt handling of any material that is submitted such as case records, x-rays, and tissue. It is planned to keep cases entered in the registry anonymous. Correspondence will be welcomed.

✦ Industrial Hygiene Briefs

Illnesses Among Workers Cleaning Condensing Tubes

IN THE DECEMBER 1952 issue of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION QUARTERLY, under "Industrial Hygiene Briefs," there appeared a report on "Occupational Illnesses of Bacterial Origin." This article was of considerable interest to us as we were called upon to investigate a similar condition in 1949, and arrived at conclusions different from those presented in the December issue of the QUARTERLY. We do not mean to dispute the findings of the author of this article but desire to call attention to another approach to a similar problem which led us to entirely different conclusions.

In June, 1949, the Medical Director of a public utility company contacted the Virginia Bureau of Industrial Hygiene for assistance in determining the cause of illnesses of the workers who cleaned the condenser tubes in a large power generating station. The following is an excerpt from our report of this first conference:

"The purpose of this conference was to discuss the operation at which employees worked when taken sick and to review the symptoms of their illnesses. The following facts were stated: All of the workers who had become ill had been cleaning the condensers. Similar illnesses had occurred starting about one year previously, but until recently these illnesses had not been related to this operation. The cleaning of the condensers consisted of removing algae type growth which forms in the condenser tubes. Some sludge is occluded in the growth. The raw river water is pumped through the tubes for cooling purposes. The frequency of cleaning depends upon the condition of the river water. Prior to this visit, there had been a dry spell. Also, dredging operations were being carried on farther upstream. Early in May, 1949, five or six workers of the condenser cleaning crew had become ill shortly after performing this operation. On June 11, 1949, the next time the condenser was to be cleaned, the number of workers performing this operation was doubled so as to decrease the time of each one's exposure. Although thirty minutes was the maximum time any one individual was allowed to remain in the condenser, approximately half of the workers became sick. It was noted that one worker was taken ill nearly every time he helped clean the condenser. No illnesses had occurred among the workers' immediate families either before or after their illnesses. At the conclusion of the conference, it was agreed that the Bureau of Industrial Hygiene would be notified the next time the condenser was to be cleaned so that samples could be collected."

The Medical Director of this company informed us that it was becoming increasingly difficult to obtain workers for this job. The symptoms of the illness resembled an upper respiratory infection, and for the lack of a better diagnosis it was called a virus infection. The onset of the illnesses generally started three to 12 hours after exposure. All of the ill workers complained of metallic tastes in their mouths. Many of these persons also had gastrointestinal upsets. Other symptoms were a feeling of malaise, difficulty in breathing, severe headache, diarrhea, chills, fever, and vomiting. These symptoms all subsided within 24 to 72 hours after their onset. However, after the June 11, 1949 cleaning, one worker was hospitalized for two days. All of the ill workers were treated with penicillin and sulfa drugs which appeared to have no effect on the recovery.

The algae growth in the condenser restricted the flow of cooling water through the tubes. When the algae growth caused excessive resistance to the water flow as indicated by the increased loss of head, the decision was then made to remove the condenser from the line to clean. Because of the heavy load on the power generating sta-

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*HUNTER, CHARLES A., PH.D., and ENSIGN, PAUL R., M.D.: An Epidemic of Diarrhea in a New-Born Nursery Caused by Pseudomonas Aeruginosa. *Amer. J. of Pub. Health*, 37:9, 1166-1169 (September) 1947.

tion, the only time the operations could be curtailed was when the load was light. Such a period occurred weekly at about eleven o'clock Saturday night. The Bureau was notified on July 9, 1949, that the condensers were to be cleaned the next night. Preparations were made to collect various samples which might be helpful in determining the cause of illness. However, upon opening the entrance door of the condenser, it was noted that there was a very small amount of algae present. The increase in resistance through the condenser was caused by leaves, sticks, walnuts, and other debris which escaped through the screen at the water intake and interferred with the water flow through the tubes. Only one entrance door was opened and a fan was not used, although it was customary to use one to circulate air during the operation. It was extremely warm and humid inside the condenser.

It should be mentioned that the stream from which the cooling water was obtained was heavily polluted, not only with domestic sewage, but also with industrial wastes. Up stream from the plant were located a number of communities which had no sewage disposal plants. A number of different kinds of chemical plants were located a short distance upstream from the power generating station and a considerable amount of waste was discharged into the stream.

Tests made inside the condenser revealed no significant concentration of combustible gases present. Tests for hydrogen sulphide were negative. Other atmospheric samples were collected for further tests in the laboratory and also a sample of the slime was scraped into a container for analysis. In searching through the literature, there appeared to be no record of any similar situations. Results of the chemical analyses of the atmospheric samples showed the following result:

Oxygen	20.8%
Carbon Dioxide	.1%
Carbon Monoxide	Negligible
Nitrogen	79.1%
Arsine (as As)	Trace

Results of the analyses of the slime (algae) showed .23 milligrams arsenic (As) per pound of wet slime. It was rather disappointing that conditions found at the time of the visit were not similar to those at the time the workers became ill. A few days after this visit a chlorinator was installed to feed chlorine to the water prior to its flow into the condenser. The addition of chlorine eliminated the algae growth and subsequently the need for cleaning the condenser tubes was unnecessary.

Two weeks later, samples of algae growth were collected at and near the water intake. These samples which were from various places on the float and pillars, both above and below the water line, were analyzed for arsenic content. The concentrations were found to vary from three to six milligrams of arsenic per pound of wet material. In the International Labor Office, Vol. I of Occupation and Health, there is a description of a typical picture of arsine poisoning among the fishermen of Frisches Haff due to the gases given off by growths similar to algae.

In the previous article in this journal the author attributed similar illnesses to bacteria identified as "pseudomonas aeruginosa." However, it appeared doubtful if this could be the cause of the illnesses in this case. In discussing an epidemic of diarrhea in a new-born nursery caused by pseudomonas aeruginosa, Hunter and Ensign* stated that the period of incubation varied from one to seven days, commonly six, and that the sulfa drugs were most effective in treatment. In the case just reported in this article, the onset of the illnesses occurred three to 12 hours after exposure and the penicillin and sulfa drugs used had no apparent effect on the length or severity of the illnesses. In cases of illness where the onset occurs a few hours after exposure, it is logical to suspect that the causative agent is a material which is readily absorbed in the body. Metal fumes, vapors and gases are readily absorbed into the bloodstream through the lungs, and symptoms of acute toxicity usually appear several hours after exposure.

Conditions in the condenser at the time of the investigation were so different from those existing when the workers were actually cleaning algae from the tubes that definite conclusion could not be reached. Chemical examination of blood, urine and fecal samples would have been of little or no value at this time since no workers were

ill. However, it is possible to point to certain facts which might be clues to these illnesses. Practically all of the symptoms of the ill individuals were very similar to those of persons exposed to volatile arsenic compounds. Since the solid material collected near the river water intake contained a significant amount of arsenic, it is possible that a hazardous concentration of volatile arsenious compounds was formed in the condenser at the time the workers cleaned the tubes. It should be remembered that the temperature in the condenser at such times was considerably above 100° F. Even though in this instance the condenser tubes were relatively clean and only a small amount of algae was formed in the bulkhead, trace quantities of arsenic were formed in the bulkhead atmosphere.

The evidence presented in the previous report in the Quarterly offered no substantiation that the illnesses were caused by bacteria identified as pseudomonas aeruginosa. Furthermore in this report evidence that volatile arsenious compounds were the cause of these illnesses was not conclusive since the use of chlorine prevented further growth of algae in the condenser tubes but at least the circumstantial evidence appeared to indicate that these compounds were responsible. If such a situation again occurs, it is hoped that the investigators will collect and analyze the blood and urine specimens from the disabled workers as well as atmospheric samples of the exposure in order to either verify or disprove any of the previous opinions which have been presented. If it is suspected that a bacteria is the causative agent, a thorough bacteriological study including examination of stool specimens should be done on all persons exposed. Pseudomonas aeruginosa could in all probability be isolated from the feces if these organisms were the cause of the disabilities.

—HARRY E. SEIFERT, Director
Bureau of Industrial Hygiene
Virginia State Department of Health

◆ *News of Local Sections*

Western Michigan Section

THE WESTERN MICHIGAN Section held its fifth annual one-day conference in Grand Rapids on May 19. The morning session consisted of the following: "Industrial Illumination," WILLIAM A. STANNARD, Consumers Power Company; "Relation of Mental Health to Industrial Production," HARRY C. YUDIN, Consulting Psychologist; and "Present Trends in Workmen's Compensation," WILLIAM A. PERKINS, Alexander, Cholette, Perkins and Conklin.

The speaker at the luncheon was PROF. JAMES HAYES, Michigan State College.

A panel on pre-placement physical examinations was offered in the afternoon. Members of the panel were: Radiologist, ARTHUR J. JOISTAD, M.D., Muskegon, Michigan; Plant Physician, E. J. LAURETTE, M.D., Campbell, Wyant and Cannon Foundry Corporation; Safety Engineer, G. DEWEY REED, Lansing, Michigan, and representing management, ANDREW EHRHARDT, Whirlpool Corporation.

The final talk in the conference was given by JOHN C. SOET, Michigan Department of Health. He spoke on the subject, "New Developments in Case Histories in Industrial Hygiene."

Ohio Valley Section

ON MAY 28, the Ohio Valley Section met in Cincinnati. The program was devoted to papers concerning recent activities of the Bureau of Industrial Health of the Cincinnati Health Department. The following program was presented: "Investigation of a Source of Lead Exposure in a Ceramics Plant," J. CHOLAK, Kettering Laboratory; "Planning and Development of a Health Program for a Small Manufacturing Plant," DR. HARRY T. OVERBY, Weber Engineered Products; "Employee Health Appraisal in an Automobile Dealer Agency," R. E. SINGLE, Queen City Chevrolet; "An Unusual Health-Safety Hazard of Steel Riggers," DR. JAMES P. HUGHES, Kettering Laboratory.

DR. EDWARD F. BUYNISKI who served as the section's representative at the Local Sections Council Luncheon reported on proceedings at the Los Angeles meeting.

Metropolitan New York Section

DR. A. G. CRANCH, Medical Consultant, Union Carbide and Carbon Corporation was the principal speaker at the May 11 meeting of the Metropolitan New York Section. He spoke on "Facts, Fallacies, and Fancies in Industrial Medicine." DR. CRANCH presented some informal reminiscences of his experiences in over 45 years of practice in the field of industrial medicine. He discussed the changing problems and viewpoints which he has encountered and presented illustrations in demonstrating his remarks. The following officers for the year 1953 were announced:

Chairman: ROBERT P. GLEASON, Sylvania Electric Products, Inc.; Chairman-Elect: CLYDE M. BERRY, Esso Standard Oil Company; Sectretary-Treasurer: E. D. PALMES, Institute of Industrial Medicine, New York University.

New England Section

ON MAY 8, an all-day session of the New England Section was held at the U.S. Submarine Base at New London, Connecticut. The morning session opened with a welcoming address by CAPT. W. B. SIEGLAFF, USN, Commanding Officer, and continued with the following papers: "Recent Developments in Submarine Medicine," CDR. DUFFNER, MC, USN, Officer in Charge, Medical Research Laboratory, Submarine Base; "Inhalation of Sulfur Dioxide by Human Subjects," DR. MARY AMDUR, Department of Industrial Hygiene, Harvard School of Public Health; "Radiation Damage from X-ray Apparatus," DR. JAN LIEBEN, Bureau of Industrial Hygiene, Connecticut Department of Health; "Performance Characteristics of Reverse Jet Filters," CHARLES E. BELLINGS, Air Cleaning Laboratory, Harvard School of Public Health; "The Industrial Hygiene Program of the Navy," LCDR. G. A. L. JOHNSON, MSC, USN. Preventive Medicine Division, Bureau of Medicine and Surgery; "Relationship of Atomic Submarine Construction to Industrial Medicine," DR. A. DUNCAN MACDOUGALL, Electric Boat Company; "Skin Penetration by the Diamines," DR. J. WISTER MEIGS, DR. L. J. SCIARINI, and W. A. VAN SANDT, School of Public Health, Yale University.

A tour of the Submarine Base occupied the entire afternoon and included guided tours through one of the famous submarines of World War II, a submarine rescue and salvage ship, and inspections of midget submarines and other waterfront and base activities. A highlight of the tour was a demonstration in the 100 foot deep training tank of submarine escape methods by free ascent and by using the Momson lung.

The chairman of the meeting was DR. J. WISTER MEIGS of the Yale University School of Public Health.

Gulf Coast Section

THE GULF COAST Section met in Houston on June 5. The President announced that the Section is sending a subscription of the AIHA QUARTERLY to all of the leading universities and colleges in the area.

HARVEY MOBLEY, Houston Industrial Hygiene Department, discussed the chief industrial operations where carbon monoxide is present. He also discussed the methods of evaluating the hazard and gave his experiences in studying carbon monoxide exposures in various types of industry.

DR. W. U. GIESSEL, Navigation Clinic, discussed the physiological effects of carbon tetrachloride. He described a recent case which occurred in a machine shop where the carbon tetrachloride exposure was from an additive to cutting oil.

M. H. TIX spoke on planning and installing local exhaust ventilation. His talk was concluded with a film supplied by the American Air Filter Company.

Michigan Section

DR. DONALD J. BIRMINGHAM, SR., Surgeon, Chief, Clinical Section, Division of Occupational Health U.S.P.H.S., was the principal speaker at the March 17 meeting of the Michigan Section. His subject was "Industrial Dermatitis" which covered aspects of recent developments in control methods. The results of the elections for 1953-54 were announced. The following were then installed as officers for the 1953-54 term: President: DON G. FOWLER, Michigan Department of Health; President-Elect: MRS. KATHLEEN KUMLER, General Motors Research; Secretary-Treasurer: FERD J. CHMIELNICKI, Detrex Corporation.

Chicago Section

THE CHICAGO SECTION held its final meeting of the season on June 3. WARREN A. COOK delivered excerpts from his Cummings Memorial Lecture, "A Unique American Institution." MR. COOK was presented with a barometer, thermometer, hygrometer from the Chicago Section as a token of appreciation of his work in Section affairs. MR. COOK assumed new duties at the University of Michigan in July. Officers for the year 1953-54 were presented:

President: HOWARD N. SCHULZ, Abbott Laboratories; President-Elect: JOSEPH A. HUBATA, M.D., Armour and Company; Secretary-Treasurer: W. T. MCCORMICK, Inland Steel Company.

✦ President's Page

IN THE back of this journal are listed the names of about 100 members who are serving on committees. Public listing is inadequate recognition of the responsibility and the burden of committee membership. From the beginning of the AIHA most of the work of the ASSOCIATION has been done by committees and there is no reason to expect the situation to change. In recent years working technical committees have become more numerous and committees intended to serve the organization or the members personally are now a smaller proportion of the total.

There is much facetious comment upon the activity of committees. A committee is a group of people who, in three hours, can decide a question which any of its members could handle in five minutes. AIHA overcomes this admitted weakness of committees by seeing that the committees seldom meet, but that they conduct most of their business by mail. One man might be able to do every concrete thing that all our committees accomplish but his efforts would not maintain the profession of industrial hygiene nor the ASSOCIATION. Shared decisions and group activity are necessary to create a professional attitude, sense of solidarity and of belonging to something.

Under the By-Laws, committee members are appointed by the President and confirmed by the Board of Directors. In practice tentative appointments are made by the President-Elect a few months before he becomes President. The list of appointments is mailed to the Directors well in advance of the annual April meeting and approval or objection is given by mail. In this way the president takes office at the annual meeting having confirmation of appointment of the committees who will work with him, during his term of office. There is no hiatus in activity while he is struggling to organize his committees.

Actually it is no struggle. Over 100 members must be contacted to determine their willingness to serve, but almost never does a member refuse. The problem is to find the capable energetic younger member who would like to serve but has never been asked. Of course the President knows the older member who has been active for years and is tempted to ask him to accept another committee assignment. Efficiency may lie in keeping constant the personnel of successful committees, but development of interest and new ideas lies in always adding new members and retiring those who have served. It is a difficult problem for the President-Elect to decide which members should be asked to serve on the various committees.

ALL THE committees are important to the ASSOCIATION and perhaps it will be possible later to outline the work and responsibilities of each of them. Those listed in the QUARTERLY are considered standing committees.

From time to time temporary committees are appointed for special tasks. Possibly the most important recent temporary committee was the Committee on Committee Activities. About three years ago it completed a document on the scope and functions of committees which is a useful guide for each newly appointed chairman.

In order to spread the work of the ASSOCIATION, to increase interest, and to disseminate information it is desirable to enlist members with no history of committee service. There is no precedent for volunteering for committee service, but such a precedent ought to be established.

Any member who is proud to belong to AMERICAN INDUSTRIAL HYGIENE ASSOCIATION and wants to be more active in its affairs should let the President-Elect know of his interest in becoming a committee member.

—HENRY F. SMYTH, JR.
President, AIHA

◆ In the News

HENRY F. SMYTH, JR., AIHA President, will be the Association's official representative at the First Scientific Meeting of the British Occupational Hygiene Society which will be held November 2 at the London School of Hygiene and Tropical Medicine. He is attending at the invitation of the Board of Directors of the British Society.

ROBERT E. ECKARDT, M.D., Redfield Village, Metuchen, New Jersey, has been appointed an Associate Clinical Professor of Industrial Medicine at the New York University-Bellevue Medical Center. DR. ECKARDT received his Ph.D. in bio-chemistry from Western Reserve University in 1940, and his M.D. from Western Reserve Medical School in 1943. He is the author of several papers dealing with carcinogenesis. In addition to his duties as Director of the Medical Research Section, Standard Oil Development Company, DR. ECKARDT is a member of the American Medical Association, the Industrial Medical Association, the Industrial Hygiene Association, the New York Academy of Medicine and the Union County Medical Society.

MORRIS B. JACOBS has been appointed Director of the Laboratory of Air Pollution Control, Department of Air Pollution Control, City of New York. DR. JACOBS was a member of the staff of the Department of Health of the City of New York for the past 25 years, his last assignment being that of Chief Organic Chemist of the Bureau of Laboratories.

MELVIN W. FIRST, SC.D., has established his own offices as Consulting and Research Engineer at 123 Wiswall Road, Newton Centre 59, Massachusetts. DR. FIRST, who has been associated with the Air Cleaning Laboratory of the Harvard School of Public Health for the past several years and was formerly with the Detroit and Michigan Departments of Industrial Hygiene, will resume his industrial hygiene engineering in addition to serving as consultant on problems pertaining to air and gas cleaning and atmospheric pollution control. He also is a member of Industrial Hygiene Associates, an enterprise which presents a complete and well-integrated industrial hygiene service to small industries and casualty insurance carriers. His associates are SAMUEL LEVIN, health physicist and FREDERICK J. VILES, JR., industrial hygiene engineer and chemist, both of the Occupational Medical Service of the Massachusetts Institute of Technology and ALBERT O. SEELER, M.D., industrial hygiene physician on the staff of the Harvard Medical School.

WARREN A. COOK, former Director, Division of Industrial Hygiene and Engineering Research, Zurich-American Insurance Companies, resigned July 1 to accept an appointment as Associate Professor of Industrial Health and Hygiene in the School of Public Health, and Research Associate in the Institute of Industrial Health at the University of Michigan, Ann Arbor.

LLOYD E. GORDON, who joined Zurich Insurance Companies in 1943 as an industrial hygiene engineer, and was made Assistant Director of the Division of Industrial Hygiene and Engineering Research in 1951, became the Division's new Director upon the resignation of Warren A. Cook, July 1.

HERBERT E. STOKINGER of Cincinnati has been appointed liaison representative to the Committee on Allowable Concentration of Toxic Dusts and Gases of the American Standards Association. MR. STOKINGER, chief toxicologist of the Chief Occupational Health Field Headquarters, U.S. Public Health Service in Cincinnati will have as his alternate, DR. W. CLARK COOPER, also associated with the Health Field Headquarters, as Medical Director. DR. COOPER is additionally an alternate member of the ASA's Safety Standards Board. This ASA committee deals with the determination of the allowable concentrations limits of harmful substances such as gases, vapors, and fumes in the atmosphere of working places, from the viewpoint of occupational disease prevention. Up to the present time, this committee has approved the maximum allowable concentrations for about 17 or 18 substances. The standards have been set up on the basis that an employee should be able to work in that concentration eight hours a day continuously, without harmful effects. The American Standards Association is the national clearinghouse for voluntary engineering, industrial, safety and consumer standards. It is made up of more than 110 technical societies and trade associations and 2300 individual company members. The Association coordinates the standardization work of many national organizations to assure standards that have inter-industry recognition on a nationwide scale.

♦ *Obituaries*

COLONEL WESLEY C. COX, MC, USA, died in Richmond, Virginia, May 22, 1953, following a cerebral hemorrhage. At the time of his death Colonel Cox was Commanding Officer of the Army Environmental Health Laboratory at the Army Chemical Center, Edgewood, Maryland. He was on leave when stricken.

Born in New York City, April 21, 1891, Colonel Cox graduated from Columbia University (A.B., 1913) and the College of Physicians and Surgeons, New York (M.D., 1916). Subsequently he took graduate training at the Army Medical School, Washington, D.C., and Johns Hopkins University (Doctor of Public Health, 1940).

Colonel Cox began his Army career in 1917 when he joined the Medical Corps Reserve as First Lieutenant. The following year he was commissioned First Lieutenant in the Regular Army. During his 36 years of service he held posts as Chief of the Laboratory, Camp Jackson, South Carolina; Epidemiologist, Fort Dix, New Jersey; Serologist and Chief, Laboratory, Eighth Corps Area; Chief, Laboratory and Medical Inspector, Fort Leavenworth, Kansas. Between other assignments he was bacteriologist, serologist and instructor at the Army Medical School, Washington, D.C., and bacteriologist and instructor, Walter Reed General Hospital.

A number of years of service were spent in the Panama Canal Department where he began his first tour of duty as bacteriologist in 1922. Leaving in 1925, he returned in 1939 to spend seven more years in the Canal Zone, first as medical inspector, then assistant department surgeon and finally as surgeon. His other chief post outside the United States was as assistant surgeon, Headquarters Caribbean Command. In 1946 Colonel Cox was called to head up the Army Industrial Hygiene Laboratory, now the Army Environmental Health Laboratory, and in 1948 was designated as Consultant to the Surgeon General on Occupational Health and Hygiene, holding both positions until the time of his death.

Colonel Cox was a fellow of the American College of Physicians, the American Medical Association, American Public Health Association and the American Geriatrics Association and was certified by the American Board of Preventive Medicine. He held memberships in the American Society of Tropical Medicine and Hygiene, Industrial Medical Association, American Industrial Hygiene Association and the Association of Military Surgeons. He was awarded the Legion of Merit by the Caribbean Defense Command, October 5, 1945, for his work on sanitation and disease control of that area, and the Army Commendation Ribbon on April 27, 1943, for his health education activities in schools of the Canal Zone. In 1946 he was honored by the President of Panama with the Order of Vasco Nunez de Balboa, Grade of Commander.

Memorial services in his honor were held in Fort Meyer chapel on May 27, 1953. He was buried in Arlington National Cemetery.

[NOTE: In the article by ALFRED N. SETTERLIND entitled, "Preparations of Known Concentrations of Gases and Vapors in Air" which appeared in the June, 1953 issue of the AIHA Quarterly, Figs. 1 and 2 were transposed. The graph labeled Fig. 1 should have been Fig. 2 and the one labeled Fig. 2 should have been Fig. 1.]

Houston Industrial Health Conference

THE SIXTH INDUSTRIAL HEALTH CONFERENCE of Houston, Texas will be held at the Shamrock Hotel, October 1, 2 and 3, 1953. The name of the recipient of the Houston Chamber of Commerce award for the outstanding contribution to the field of industrial hygiene will be announced at the Conference. The organization award will also be presented during the meeting. This award recognizes a company, foundation, or group, which has promoted industrial hygiene and health in the most noteworthy manner. The keynote address will be delivered by R. B. KAHLE, President, Eastern States Petroleum Company, Houston. Panel discussions will augment the talks of the many distinguished speakers at the conference. In addition to the above-mentioned sessions, the conference offers unofficial dinners, Shamburger parties and a tour down the ship channel aboard the Sam Houston.

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